1975

Transactions Index-Abstracts

SAE

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INDEX-ABSTRACTS

of November 1977

SAE TRANSACTIONS
AND LITERATURE DEVELOPED DURING 1975

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AWARDS

L. RAY BUCKENDALE LECTURE

The L. Ray Buckendale Lectures, inaugurated in 1954, commemorate the contributions of the 1946 SAE President as a developer of the latent abilities of young men and as an authority in the theory and practice of gearing, particularly as applied to automotive vehicles.

A cash award and certificate are provided for an annual lecture and monograph by a distinguished authority in the technical areas of commerical or military ground vehicles for either on- or off-road operation.

The Lectures are directed toward filling the needs of young engineers and students for up-to-date practical knowledge.

Heavy-Duty Truck Suspensions

Truck suspensions for heavy-duty trucks perform complex and conflicting functions and have been the subject of much development. This paper provides information on many types of suspensions presently in use and indicates those applications for which the particular types of suspensions in use are best suited. While primary emphasis is placed on leaf spring suspensions, data are also provided on other types of suspension such as rubber, air, torsion bar, and solid mount suspensions which are in current use.

E. R. Sternberg
Truck Group, White Motor Corp.

Ernest R. Sternberg is presently Engineering Consultant to the Truck Group, White Motor Corp. Prior to his retirement in early 1975, he was Director of Engineering of the Truck Group.

Mr. Sternberg joined the Sterling Motor Truck Co., Inc., in 1934, and he has served as Sales Engineer, Director of Materials, Director of Engineering, and Vice President.

In 1951, Mr. Sternberg became General Manager of the Sterling Division of the White Motor Co. and subsequently was transferred to the home office of the White Motor Co. in Cleveland, as Assistant to Vice President of Production. In 1957, he was placed in charge of Truck Engineering for the Autocar Division at Exton, Pennsylvania, and returned to Cleveland in 1959 to become Chief Engineer and then Vice President of Engineering of the White Truck Division.

In early 1970, Mr. Sternberg was assigned to the Corporate Engineering Staff, but he then became Director of Engineering of the Truck Group of the White Motor Corp. in 1972.

An SAE member since 1940, Mr. Sternberg served on the Technical Board and the Automotive Council and also served two terms on the General Standards Council of which he was the 1965 Chairman. He holds a Bachelor of Science Degree in Mechanical Engineering from the University of Southern California and a Master's Degree in Mechanical Engineering from the University of Wisconsin.

HORNING MEMORIAL AWARD

The Horning Memorial Award is granted annually to the author of the best paper relating to the adaptation of fuels to internal combustion engines, or the adaptation of internal combustion engines to fuels, which has been presented at a meeting of the Society during the calendar year. Papers are judged primarily for their value as new contributions to existing knowledge of the art of such adaptation.

One of Harry L. Horning's deep interests was the establishment of a broadly cooperative agency devoted to the better mutual adaptation through experimental effort of fuels and internal combustion engines, including the development of an internationally recognized standard for testing fuels. He was a major force in the movement to bring the automotive and petroleum industries together to deal with the fuel problem.

One Hundred Years of the Otto-Cycle Engine

This paper is presented in observance of the centennial of the Otto-Cycle engine. Although it briefly traces the history of the engine, it is largely devoted to the dramatic effects that the engine and the vehicles it powers have had on the way people live. The economic importance of automotive transportation in the United States and the rest of the world is discussed, as are the relative roles of mass transit and automobiles in moving people.

Harold J. Gibson, Manager of Ethyl Corporation's Detroit Research Laboratories, has devoted over 45 years to research in the mutual adaptation of engines and fuels.

Born in Wixom, Michigan, Mr. Gibson earned a B. S. degree in Mechanical Engineering in 1929 and an M. S. degree in Mechanical Engineering in 1930 from the University of Michigan. He then joined Ethyl's Detroit Research Laboratories as a research engineer. The intervening years have been spent by Mr. Gibson on the development of methods and equipment for evaluating the performance of motor fuels, and the development of fuels, lubricants, and engines for power, economy, durability, and low emissions. During World War Two, he conducted engine and fuel evaluations for the U. S. Army Ordnance Department and the National Defense Research Council. Mr. Gibson was named the Ethyl Laboratories' research coordinator for fuels and lubricants in 1944. This was followed by positions as research supervisor, director of products application, technical director of the Laboratories in 1955 and manager of the Laboratories in 1963.

Mr. Gibson has made numerous contributions to technical literature, primarily in the interrelated fields of automotive fuels, lubricants, and engines. He participated in the activities of the Coordinating Research Council for 20 years and is a former chairman of the Motor Fuels Division of that organization. As an active member of the Society of Automotive Engineers since 1932, his activities have included serving as chairman of the Science-Engineering Activity for three years and as current chairman of the Transportation Systems Activity. His other memberships include Sigma Xi, Pi Tau Sigma, and the Engineering Society of Detroit, of which he is a Fellow. During the last 10 years, he has traveled extensively in Europe, Africa, the Middle East, and Japan while serving as a technical consultant to Ethyl's International Division.

Harold J. Gibson
Research Labs., Ethyl Corp.

MANLY MEMORIAL MEDAL

The Manly Memorial Medal is awarded annually to the author of the best paper relating to the theory or practice in the design or construction of, or research on, aerospace engines, their parts, components, or accessories.

Eligible are papers presented before SAE national and section meetings. Papers are judged for their value as a contribution to the knowledge of the aerospace art.

They are not judged upon the value of any mechanical development or invention already known that may be described in the paper.

The Award is given in memory of Charles Matthews Manly as a tribute to the many contributions he made in the fields of automotive and aeronautic engineering. Established in 1928, the scope of the award was broadened in 1960 to include advances in the aerospace field.

Engine Design Considerations for 2nd Generation Supersonic Transports

The environmental and economic goals projected for advanced supersonic transports will require revolutionary improvements in propulsion systems. Variable cycle engine concepts that incorporate unique components and advanced technologies show promise in meeting these goals. Pratt & Whitney Aircraft is conducting conceptual design studies of variable cycle engine concepts under NASA sponsorship. This paper reviews some of the design considerations for these engine concepts. Emphasis is placed on jet noise abatement, reduction of emissions, performance improvements, installation considerations, hot-section characteristics and control system requirements. Two representative variable cycle engine concepts that incorporate these basic design considerations are described.

Robert A. Howlett
Pratt & Whitney Aircraft Div., United Aircraft Corp.

Robert A. Howlett is Pratt & Whitney Aircraft's program manager for advanced supersonic propulsion studies. In this position, he is responsible for the preliminary design and evaluation of conventional and variable cycle engines for advanced supersonic transports, including NASA-sponsored supersonic engine studies. Another aspect of his responsibility is the planning of advanced technology programs that would eventually lead to the capability for a United States entry into the supersonic transport market. Prior to his present assignment, Mr. Howlett has conducted advanced engine studies for other commercial and military applications including STOL aircraft and marine propulsion systems. His background includes reliability and cost-effectiveness evaluation of aircraft and space systems and experimental research in liquid-metal cooled reactor systems. Mr. Howlett, a member of Tau Beta Pi, received his BSME from the University of Massachusetts and his MSME from Rensselaer Polytechnic Institute. He recently served on the Connecticut Section Council of AIAA and holds a registered engineering license in Connecticut.

Gerald W. Nyquist and Clarence J. Murton / Static Bending Response of the Human Lower Torso - 751158

Gerald W. Nyquist earned his B.S. and M.S. degrees from Lawrence Institute of Technology and Wayne State University, and he received a Ph.D. in Applied Mechanics from Michigan State in 1970. He is a registered professional mechanical engineer, and holds memberships in SAE, ASME, and Sigma Xi. Past employment has included test engineering at Ford Motor Company and Biomechanics research at Wayne State University. He joined General Motors Research Laboratories in 1972, and is currently a GM Environmental Activities project engineer.

Clarence J. Murton hails from upstate New York. He attended the University of Michigan, and has served in the U.S. Navy. Following many years of employment with City Pattern Corporation in Detroit, Mr. Murton joined Wayne State University in 1963, where he is currently a laboratory supervisor in the Biomechanics Research Center. In this capacity, he has been active in a number of significant automotive safety research programs.

The papers honored in this section have been judged to be of significant value to the permanent literature. These papers, and only these, may be referred to as the Transactions of the Society.

The full papers and their discussions are published in a microfiche edition, or in supplementary bound volumes. Also, individual papers are permanently available from the Society in film or photocopy form.

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Included are abstracts of the papers judged to be the Transactions of the Society. Each such paper is noted by "SAE Transactions" following the abstract, along with a listing of discussers.

All literature is permanently available in film or photocopy form. Transactions papers and discussions are also issued in supplementary bound volumes.

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ABSTRACTS

750002. Improving the Measurement of Chassis Dynamometer Fuel Economy. Bruce H. Simpson, Ford Motor Co.

Obtaining vehicle fuel economy data in conjunction with chassis dynamometer emissions testing is a useful, convenient technique. Data derived in this manner, using EPA city and highway driving cycles, are in wide use. Fuel economy results obtained by carbon mass balance calculation of carbon containing compounds in the vehicle exhaust are at least as accurate and repeatable as those obtained by direct measurement of fuel consumed. Nevertheless, the overall chassis dynamometer-carbon balance fuel economy test yields undesirable variation of results and needs refinement. Major factors influencing the accuracy and repeatability of test results are: CO_2 measurement accuracy; variations in following the driving cycle; vehicle-dynamometer interface conditions; and associated calibration, calculation, test technique and procedural methods and controls employed. Each of these factors is discussed in terms of its relative importance and causal factors, along with suggested or potential means for improvement.

1975 SAE Transactions

750003. Measurement of Motor Vehicle Operation Pertinent to Fuel Economy. T. M. Johnson, D. L. Formenti, Richard F. Gray and William C. Peterson, Noise and Vibration Laboratory, General Motors Proving Ground.

Information about public driving patterns was collected in three ways.

1. Chase Cars, equipped with instrumentation, were used to monitor 2,500 randomly selected trips in various parts of the United States. Data relating to 11,000 miles of operation was thereby recorded and analyzed.

2. Long duration strip-chart recorders were installed in vehicles in use by the public. These devices recorded traces of speed versus time, while the vehicles were in motion. More than 12,000 miles of driving were recorded.

3. Passive electronic recording devices were installed in selected vehicles which were in use by the public. These devices recorded the portion of miles driven within various speed bands. In this manner, more than 61,000 miles have been recorded. This study is still in progress and is intended to monitor long-term trends in customer operation.

1975 SAE Transactions

750004. Passenger Car Fuel Economy as Influenced by Trip Length. Thomas C. Austin and Karl H. Hellman, U.S. Environmental Protection Agency.

Data from the Nationwide Personal Transportation Study (NPTS) and other sources have been used to generate distributions of vehicle miles traveled (VMT), average speed, and fuel consumption as a function of trip length. Approximately one third of all automobile travel in the U.S. is seen to consist of trips no more than ten miles in length. Because short trips involve more frequent stops and a smaller percentage of operation during warmed-up conditions, nearly half of the fuel used by automobiles is consumed during the execution of these short trips.

The typical trip of approximately ten miles in length has been shown to result in a fuel economy that is equal to the average fuel economy achieved for all trips combined. NPTS data on average speed versus trip length and General Motors data on stops/mile versus average cycle speed indicate that the major characteristics of the trip that results in a fuel economy equal to the overall fuel economy are an average speed of 24.5 mph and 1.4 stops per mile. The composite of the U.S. Environmental Protection Agency city and highway driving cycles is 26.6 mph and 1.4 stops per mile.

1975 SAE Transactions

750005. A Study of Technological Improvements in Automobile Fuel Consumption. David A. Hurter and W. David Lee, Arthur D. Little, Inc.

A study was conducted to determine the potential reduction in automotive fuel consumption based on the use of innovative systems and improved components. Technological areas investigated were: spark ignited engines with and without turbocharging, electronic feedback controlled fuel injection with dual bed catalytic converters, stratified charge combustion, light weight diesels, lock-up torque converters, continuously variable ratio transmission, tires aerodynamic drag, vehicle weight, engine accessories and optional equipment.

Standard and compact-size 1973 model year vehicles were selected for analysis using a computer-simulation program to predict fuel usage and performance with and without incorporation of the improvements. In addition estimates were made as to whether modified vehicles complied with study constraints such as emission, safety, noise and user requirements. Cost effectiveness, manufacturing adaptability and probable time frame for introduction of improvements were also estimated.

The study results indicated that the goal of 43% improvement in fuel economy (mpg), or 30% reduction in fuel usage (gpm) of a 1973 model year compact and standard size vehicle could be attained on a mass produced scale by the early 1980s.

750006. The Development of the New SAE Motor Vehicle Fuel Economy Measurement Procedures. The SAE Fuel Economy Measurement Procedures Task Force

A new fuel economy test procedure has been developed for passenger cars and light trucks that is basically similar to the established procedures used by U.S. automobile manufacturers. The new SAE procedure provides a standardized method for use in obtaining and comparing vehicle fuel economy values that relate to average conditions encountered in various modes of driving. The various aspects of the program discussed in the paper include road versus laboratory testing; existing proce-

dures; evaluation, comparison and selection of test cycles; test repeatability amongst facilities; relation of test results to those obtained in actual customer usage; comparison of independent consumer survey results; and correction factor development and application.

1975 SAE Transactions

750007. Performance Characteristics of Elastomeric Bumper Fascia. Hartley A. Silverwood, Davidson Rubber Co., Inc., McCord Corp.

This paper presents a comparison of material performance, processing differences, and cost implications as related to three material candidates for automotive exterior fascias. The three material candidates are reaction molded thermoset urethane, thermoplastic urethane, and glass-fiber reinforced EPDM rubber.

750008. The Shock Isolator for the Bumper System. Yasuhiko Tsuzuki and Akira Suganuma, Toyota Motor Co., Ltd. (Japan); Hiroyuki Ono and Toshimitsu Kobayashi, Aisin Seiki Co., Ltd. (Japan).

Through our development work on a bumper system that would meet the requirements of FMVSS No. 215, "Exterior Protection of Passenger Cars," the correlation between the physical properties of the compressible solid, and the mechanical structure and load-deflection characteristics of the shock isolator system has been clarified.

A number of silicone rubbers were investigated and their molecular weight and cross-linking density changed. The results of these investigations have been applied to the new shock isolator system of our 1974 model vehicles.

750009. Unrepaired Crash Damage—Implications for Cost-Benefit Analyses. James Casassa, II and Wayne W. Sorenson, State Farm Mutual Automobile Insurance Co., Brian O'Neill, Insurance Institute for Highway Safety; and Sandra Stone, Arthur D. Little, Inc.

A major difficulty in performing cost-benefit analyses of bumper designs is the fact that much of the damage from low-speed crashes is never reported either to public agencies or insurers. Much of this unreported crash damage remains unrepaired, at least for some time after the crash, and thus surveys of unrepaired crash damage can provide one source of data for some of the unreported crash damage.

During the summer of 1974, surveys of unrepaired crash damage were conducted in seven metropolitan areas. The results of these surveys are presented.

It is concluded that the present state of knowledge on the frequency and amount of unreported crash damage is too limited to enable this essential component to be adequately incorporated into cost-benefit analysis of bumper designs.

1975 SAE Transactions

750010. Dunlop Composite Energy Absorbing Bumper Systems. D. A. Newton, Dunlop Ltd., Polymer Eng. Div. (United Kingdom).

This paper describes the application of composite laminates consisting of bonded rubber and plastic layers to discrete energy absorber units and flexible bumper systems.

These laminates are manufactured by the fusion bonding technique applied to injection moulding of discrete EA units and thermoforming of resilient EA bumpers.

The two material construction allows greater design flexibility in unit and system design. The properties of the dual material system permit a high ratio of energy absorption per unit weight coupled with full recovery of pre-impact configuration.

The performance and installation requirements of the 'V' shaped discrete bumper mountings is described in detail. Experimental developments in fully flexible bumpers are then discussed.

1975 SAE Transactions

750011. The Application of Elastomeric Buckling Columns in an Energy Management Bumper System. J. H. Tundermann, International Nickel Co., Inc., G. M. Larson, Pioneer Engineering and Manufacturing Co.; and R. B. Anderson, Pfizer, Inc.

In an Energy Management Bumper System (EMBS) maximum energy-absorption efficiency is achieved with a "square wave" load/deflection response. The laboratory and barrier impact tests conducted in this study show that elastomeric columns provide essentially square wave response during the buckling stage of column deflection. Of the materials tested, high diene-low Mooney EPDM (terpolymer of ethylene, propylene and a diene) materials fabricated into hollow cube absorber units exhibited square wave efficiencies of 85-90% and were found to be the most suitable elastomers for an EMBS application.

The efficient use of the elastomeric absorbers in an EMBS was accomplished by placing a metal face plate in front of the units to distribute the impact force across the face of the vehicle. This concept was applied to an engineering design for a 3000 lb vehicle EMBS that would handle impacts at 5 mph in compliance with Federal Motor Vehicle Safety Standard No. 215.

750012. Application and Testing of an Internal Air Cushion Bumper on a Structurally Modified Automobile. Ernest J. Merz, Safety Consultants; and James E. Greene, Calspan Corp.

A modified version of the pneumatic air cushion bumper has been incorporated into the basic design of a prototype automobile designed to provide improved structural performance during front, side, rear, and rollover collisions. A simple air bladder, recessed within a high-strength bumper bar, was supported by the front cross member of a modified frame which also served as a supplementary volume to reduce peak pressures and

loads. Check valves were located between the bladder and the frame chamber to limit energy of rebound. Test results showed that the design is suitable for incorporation into vehicles intended to withstand barrier crashes of 5–10 mph.

1975 SAE Transactions

750013. The Technique of Front-Wheel-Drive in Europe. H. Seznec and H. Lagrange, Regie Nationale des Usines RENAULT Centre Technique de Rueil (France).

During the past two decades, front-wheel-drive architecture has grown enormously in Europe.

This trend can be explained by the need to provide compactness, large inside space, and good road holding.

The paper describes technical problems that arise when designing a front-wheel-drive car and quotes the various technical solutions in current use.

The authors conclude that a preference for front-wheel drive will last for a long time.

1975 SAE Transactions

750014. Design Considerations for Full-Size, Front-Wheel-Drive Vehicles. Donald L. Nordeen, Richard C. Manwaring and Dennis E. Condon, Oldsmobile Div., General Motors Corp.

This paper is a progress report on the marketing, evolution, and design considerations for full-size, front-wheel-drive cars. Usage of front-wheel drive has been expanded since the initial Oldsmobile Toronado in 1966 with the introduction of the Cadillac Eldorado in 1967 and other commercial applications for motor homes and limousines. Design refinements and improvements are described along with changes made to meet marketing requirements. A comprehensive discussion of design considerations unique to full-size, front-wheel-drive cars is included. Design differences between front-wheel drive and rear-wheel drive cars are emphasized. Design freedoms, design constraints, advantages, and disadvantages of full-size, front-wheel-drive vehicles are summarized.

750015. Why Front-Wheel Drive? P. G. Tronville, FIAT S.p.A.

Front wheel drive has found wide acceptance and increased popularity during recent years in medium and medium-small class European cars. A frequent design configuration is the FWD with transverse front engine.

The principal factors in this choice are:

1. Better use of available space
2. Production costs at levels competitive with other design arrangements
3. Ease of obtaining derivative models from basic cars.

The technical/functional aspects of the FWD will not be discussed here except some reference needed to explain otherwise uncomprehensible concepts.

750016. Paper Powerplants Promote Performance Progress. Daniel S. Sanborn, McCulloch Corp.

Development and application of computer analysis to the flow system of the internal combustion engine is discussed. Particular attention is directed to the crankcase-scavenged, two-stroke-cycle, spark ignition engine, with the objective of optimizing the relationships between its complex transient flow processes and its basic mechanical simplicity. The aspects of specific output and fuel consumption, as well as those of the emission of noise and other obnoxious constituents of the exhaust, are considered. A systematic procedure is presented for determining the most practical port and duct dimensions for a new engine application.

1975 SAE Transactions

750017. Teledyne Continental Motors Red Seal Engines First CPCS Application. Jose F. Requeiro, Teledyne Continental Motors.

Teledyne Continental's new Red Seal industrial engine line incorporates the Controlled Pressure Combustion System (CPCS) featuring emissions control, fuel efficiency and driveability, without sacrificing maximum power. These new, low maintenance engines are based on time-proven mechanical components with a new cylinder head, carburetor and electronic ignition.

The complete R & D history of the program is presented, covering cylinder head, carburetion and ignition system.

The paper describes an Automotive Program with two cars, matched and optimized to meet the 1975 Light Duty Automotive Standards without using any exhaust after treatment or other emissions control devices.

750021. Computer Aided Design of Body Roof Side Rail. Conrad S. Allman, Jr., Chrysler Corp.

Using the Body Roof Side Rail as a typical design project, manual and Computer Aided Design graphics techniques were compared to explore the design areas for effective utilization of Computer Aided Design techniques. Computer Aided Design techniques were demonstrated to be most effective in reducing data acquisition efforts, in relieving the designer of noncreative design tasks, and in reduced real time design when coupled with an orderly approach to Computer Aided Design.

750023. An Analytical Evaluation of the Effect of Leakage on NO Emissions from a Rotary Engine. F. D. McCuiston, Jr., Ford Motor Co.

A mathematical model describing the Wankel engine combustion process is developed to evaluate the effects of apex-seal leakage on NO emissions. It is assumed that leakage occurs only during combustion and expansion and that only unburned gas leaks out during combustion and that during expansion, only burned gas leaks out.

A parametric study is performed to show the effects of such variables as equivalence ratio, compression ratio and engine speed. An experimentally obtained pressure time trace is used to show the accuracy of the model

predictions.

It was found that under normal operating conditions (near $\phi = 1$), reductions in apex-seal leakage area will not cause an increase in NO emissions and that below 2500 rpm, mass leakage drastically increases with further reductions in speed.

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750024. Time Resolved Measurements of Exhaust Composition and Flow Rate in a Wankel Engine. Colin R. Ferguson, Guido A. Danieli, John B. Heywood and James C. Keck, Massachusetts Institute of Technology.

Measurements were made of exhaust histories of the following species: unburned hydrocarbons (HC), carbon monoxide, carbon dioxide, oxygen, and nitric oxide (NO). The measurements show that the exhaust flow can be divided into two distinct phases: a leading gas low in HC and high in NO followed by a trailing gas high in HC and low in NO. Calculations of time resolved equivalence ratio throughout the exhaust process show no evidence of a stratified combustion.

The exhaust mass flow rate is time resolved by forcing the flow to be locally quasi-steady at an orifice placed in the exhaust pipe. The results with the quasi-steady assumption are shown to be consistent with the measurements. Predictions are made of time resolved mass flow rate which compare favorably to the experimental data base.

The composition and flow histories provide sufficient information to calculate the time resolved flow rates of the individual species measured. The information so generated shows most of the NO is exhausted with the leading gas while most of the HC is exhausted with the trailing gas.

Discussion: F. V. Bracco, Guggenheim Labs., Princeton University.

1975 SAE Transactions

750025. The Effect of Exhaust Recycle on Knock-Limited SI Engine Performance. James L. Hodges, Rensselaer Polytechnic Institute.

This paper reports on some recent work performed to establish the effectiveness of exhaust gas recycle as a knock suppressant in spark ignition engines, and to determine the effect of fuel and engine operating conditions on knock-limited engine performance and NO_x emissions.

Performance was evaluated with two different fuels: ASTM isooctane and ASTM 80 octane.

With ASTM 80 octane fuel, operating near stoichiometric, the higher knock-limited compression ratio (klcr) resulted in a break mean effective pressure (bmep) which was constant for moderate recycle, falling only with high recycle rates. Brake specific fuel consumption (bsfc) decreased with recycle to a minimum, and then increased for higher recycle rates. For lean mixtures, however, bsfc increased steadily with recycle. Performance was similar with the isooctane. The performance recovery for stoichiometric and rich mixtures (low to moderate recycle) was attributed to the higher klcr and changes in the specific heat ratio. The observed degradation in performance recovery for lean mixtures and high recycle rates was due to losses associated with the lower burning rates.

750026. Measurement and Analysis of Engine Pressure Data. David R. Lancaster, Roger B. Krieger and John H. Lienesch, Research Labs., General Motors Corp.

This paper provides a user oriented description of techniques for the measurement and analysis of engine cylinder pressures. These techniques were developed for piezoelectric transducers and for digital systems of data acquisition and analysis. Test cell procedures are described for transducer preparation and calibration, and for association of each pressure with its appropriate crank angle. Techniques are also described for evaluating the accuracy of pressure data and for eliminating specific errors. Two examples of uses for pressure data are discussed: the calculation of heat release rate in conventional engines, and the computation of internal flows in divided chamber engines.

Discussion: William L. Brown, Not available.

1975 SAE Transactions

750027. An Examination of the Performance of Spark Ignition Engines Using Hydrogen-Supplemented Fuels. J. F. Stocky, M. W. Dowdy and T. G. Vanderbrug, California Institute of Technology.

The performance of a hydrogen-supplemented fuels system is predicted using a semiempirical model. The prediction of this model is compared to data obtained during engine dynamometer tests of a hydrogen generator/multicylinder engine system. The test data and the predictions are also compared to the fuel consumption and emissions of the same engine in its stock configuration and indicate that the hydrogen-supplemented fuels system can improve BSFC 10–15% and simultaneously reduce NO_x emissions to a level consistent with the 1977 EPA standard. The performance of an optimized hydrogen generator/engine system is estimated. With these comparisons and estimates used as a basis, the potential of the hydrogen-supplemented fuels system is identified.

750028. Digital Data Acquisition with Emphasis on Measuring Pressure Synchronously with Crank Angle. Russell V. Fisher and James P. Macey, Research Labs., General Motors Corp.

A general purpose data acquisition system has been developed which converts analog data to scaled, tabulated, and graphical output. A scanning synchronization unit ensures that each input channel is sampled synchronously with input data pulses. System input can be either direct from the test area or from an analog tape recorder, in which case time expansion is possible by the use of high record–low play/back speeds.

A computer program controls the analog to digital conversion process. The on-line control of the program minimizes the subsequent data reduction, and through the use of input parameters, flexibility is attained in data formatting. The data reduction error is less than 1% and statistical programs included in the system provide estimates of the quality of the input data. The entire system including all associated hardware and software is described in detail, using acquisition of pressure data synchronously with crank angle as an example.

750029. Noise Reduction of a U.S. Army 5-Ton Truck. James E. Masiak, H. L. Blachford, Inc.

Research is demonstrating that it is possible to significantly reduce the in-cab noise levels of the Army's current truck fleet, with accompanying exterior noise reduction. Results are applicable to future Army trucks as well and are reported on a program utilizing a 5-ton Army truck. This type of truck was found generally to exceed the applicable limits established in the new MIL-STD 1474, "Noise Limits for Army Material."

The program identified major noise sources and important paths for sound to enter the cab and resulted in the selection of optimum sound absorption, sound barrier and vibration damping materials. The effect of a prototype exhaust system and its placement relative to the cab and the importance and optional means of controlling cooling fan and engine noise were also investigated.

750030. Engine Cooling System of Military Combat/Tactical Vehicles. J. P. Chiou, University of Detroit.

Military combat/tactical vehicles, such as tanks, are designed to be deployed and operated constantly in close proximity to the enemy fire. In order to provide sufficient protection for the engine and its vital systems, they are located in an almost completely enclosed and heavily armored compartment ventilated through highly restricted ballistic grilles. The space available for the cooling system in the engine compartment is limited. The heat rejection rate from various sources is high. The cooling air flow path is clumsy; repeated enlargements and reduction of the air flow sectional areas, complemented by possible bending and twisting, are common. The effective cooling air temperature is much higher than that of the ambient. All these factors alone make the cooling system designs of the subject vehicles quite different from that of the commercial vehicles, not to mention the severe military environment within which the cooling system must function properly.

This paper is a presentation of unclassified technical information directly related to the cooling system design of the subject vehicles. Severe military environment and its impact on the cooling system design are discussed. Characteristics of major components, such as ballistic grilles and their air resistance data, are presented. Typical arrangements of air flow path and liquid flow path are described. Basic design methods are discussed. Important references issued by various Army agencies are presented.

1975 SAE Transactions

750031. The Government's Role in Automotive Quality. Andrew G. Detrick, Natl. Highway Traffic Safety Admin., U.S. Dept. of Transportation.

Motor vehicle accidents resulting in injuries and deaths are caused by a variety of reasons. Quality control problems, resulting in vehicle defects, contribute to these accidents. Reduction in motor vehicle accidents is worthwhile. The National Traffic and Motor Vehicle Safety Act of 1966 through the Office of Defects Investigation, National Highway Traffic Safety Administration, provides a means of administering the manufacturers' and government's corrective action for those potential accidents caused by vehicle defects.

750033. Organizing for Quality. Richard M. Miller, American Motors Corp.

The challenges which face industry today have placed increased emphasis upon quality control functions related to pre-production planning. Product quality can be realized only by specific programs directed towards the marshalling of the people forces of an organization for quality achievement. The modern quality control engineer will interface with other corporate activities such as styling, product engineering, manufacturing engineering, and purchasing to assure satisfactory product quality. This paper will describe some of the techniques adopted by American Motors' quality control activities to facilitate attainment of quality objectives on new products introduced to the marketplace.

750034. Automatic Truck Cab Welding Facility. V. F. De Crausaz, Chevrolet Div., General Motors Corp.

Chevrolet's automatic truck cab spot-welding facility has several features that make it unique in the automobile industry. The mechanical complexity, computer control system, and physical size of the facility help to increase quality and productivity.

1975 SAE Transactions

750036. Quality Improvement Through Value Engineering. H. D. Voegtlen, Hughes Aircraft Co.

The nature and objectives of the quality control and value engineering programs are examined. Value engineering is shown to be a powerful tool to achieve overall quality objectives. Some results of VE studies at Hughes Aircraft Company and in other industries are reviewed. It is shown that these results have produced substantial cost reduction as well as other important quality benefits.

750038. The SAE Cumulative Fatigue Damage Test Program. Lee Tucker, Deere & Co.; and Stephen Bussa, Ford Motor Co.

Results of the SAE Fatigue Design and Evaluation Committee, Cumulative Damage Division test program are reported. This includes a description of the test specimen geometry, variable amplitude load histories, material properties and fatigue data. The data set produced can be used to generally evaluate methods of fatigue life prediction and laboratory simulation.

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750040. Fatigue Life Predictions for a Notched Member under Complex Load Histories. R. W. Landgraf and F. D. Richards, Scientific Res. Staff, Ford Motor Co.; and N. R. LaPointe, Product Dev., Ford Motor Co.

Three computer programs are presented for predicting the fatigue life of notched members undergoing complex load histories. The programs, while differing in terms of required information, employ a common approach involving the determination of the material response at the notch root, an assessment of damage based on closed hysteresis loops, and a linear damage summation to predict life. Agreement between predictions and experimental results generated by the SAE Fatigue Design and Evaluation Committee is reasonably good. The programs have purposely been kept simple to allow for easy modification. Applications and limitations of the three programs are discussed.

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750041. A Finite Element and Cumulative Damage Analysis of a Keyhole Test Specimen. G. E. Barron, A. O. Smith Corp.

The Cumulative Damage Division of the SAE Fatigue Design and Evaluation Committee recently finished an extensive fatigue test program. This test program involved one Keyhole test specimen, two different materials, three loading spectrums and the cooperation of eight test laboratories to run the 58 specific fatigue tests. The objective of the overall division program was to determine the state-of-the-art of cumulative damage life prediction capability using the experimental data for correlation.

This work reports a finite element and damage analysis of the Keyhole test specimen. The calculated notch root strain was compared with the experimental strain. The calculated stress and strain were used in a cumulative damage procedure to predict life for both materials subjected to various load levels for each of three loading spectrums. The results of the theoretical life predictions are compared to the experimental results.

750042. Spectrum Fatigue Life Predictions for Typical Automotive Load Histories and Materials Using the Sequence Accountable Fatigue Analysis. J. M. Potter, Air Force Flight Dynamics Laboratory.

In the course of the SAE Cumulative Fatigue Damage Test Program coupons of two steel materials were tested under three different loading histories typical of those seen at different locations in an automotive structure. Variations in the materials, spectra and loading severity caused the resulting fatigue crack initiation lives to range from the very low-cycle to the very high-cycle fatigue regime. This paper documents the procedure used in applying the Sequence Accountable Fatigue analysis to make crack initiation life predictions for the applied spectrum loading conditions. These predictions compare favorably with the measured data for both materials under the variety of loading spectra and severities seen in the SAE program.

1975 SAE Transactions

750043. Accuracy of Simplified Fatigue Prediction Methods. Lee Tucker, Stephen Downing and Louis Camillo, Materials Research, Deere & Co.

Three simplified procedures for predicting fatigue life are compared with actual test results. The part geometry, load histories, material properties, and test results used in these analyses were obtained from the SAE Fatigue Design and Evaluation Committee's Cumulative Fatigue Damage Test Program. The purpose of this effort is to evaluate the relative accuracy and applicability of these frequently used methods.

750044. Sulfidation Corrosion of Nickel-Base Exhaust Valves. Gary C. Clark, TRW Inc.

Severe corrosion was observed in the neck area of Inconel 751 material exhaust valves operated in an ebulient-cooled natural gas engine. The type of corrosion was identified as sulfidation attack. Deposits removed from the valves consisted mainly of calcium sulfate ($CaSO_4$) from oil additives and carbon (C) residue from combustion products. Experimentation showed that the presence of C was a necessary pre-requisite for attack. Based on this information, the corrosion mechanism must involve the reduction of the sulfate by C. The reduction of the sulfate results in a high sulfur chemical potential at the alloy surface making transport of sulfur into the substrate a highly favored step.

Aluminizing the Inconel 751 material proved to be an effective deterrent against sulfidation attack.

1975 SAE Transactions

750045. Predictions of Cumulative Fatigue Damage Using Condensed Load Histories. Drew V. Nelson and H. O. Fuchs, Stanford University.

This paper presents predictions of fatigue crack initiation life for three distinctly different, irregular load histories, each applied to keyhole-notched compact tension specimens at several maximum load levels and using two different structural steels. Work leading to this paper was done in conjunction with the cooperative research program of the SAE Fatigue Design and Evaluation Committee. Three computerized prediction methods (Landgraf, Wetzel, and a Nominal Stress Range approach) are used. All predictions are based on load histories condensed to 10% of their original number of reversals by the "Racetrack Method." This method, which is described in detail, selects the most damaging overall ranges in an irregular load history while preserving the sequence of the original loading. Predictions are compared with test data for the two dozen combinations of loading type and level and steel used. Comments are made on the relative merits of the different prediction methods.

1975 SAE Transactions

750046. A Comparison of Two Cycle Counting Algorithms. J. M. Potter, U.S. Air Force Flight Dynamics Laboratory.

Two cycle counting algorithms, based on Range Pair and Rainflow methodologies, are compared using three typical automotive load histories. The range pair algorithm produced typically 60–90% of the load amplitude cycles and thus less fatigue damage than the rainflow algorithm. Additionally, the rainflow algorithm requires more computer core space and 50% more computer time to cycle count the same number of load spectra than needed by the range pair algorithm. As a result, the rainflow algorithm is recommended over the range pair algorithm.

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750047. A Fracture Mechanics Fatigue Analysis of Two High Strength Steels for Tractor Equalizer Bar Application. Robert D. Week, American Hoist & Derrick Co.; and Ralph I. Stephens, Materials Engrg. Div., University of Iowa.

Using linear elastic fracture mechanics concepts, two steels quenched and tempered to Rockwell C 40-47 were evaluated for application in crawler tractor main frames. These high strength steels were D6-B and an experimental steel whose chemistry was optimized using a digital computer procedure referred to as the CHAT system, an acronym standing for Computer Harmonized-Application Tailored. Fatigue crack growth rate da/dN versus ΔK for constant amplitude loading and plane strain fracture toughness K_{Ic} parameters were determined from compact specimens. These parameters together with approximate stress intensity calculations were utilized to estimate component fatigue crack growth life assuming various initial crack sizes. These estimations were compared with accelerated component fatigue life, which included both crack initiation and crack growth.

750048. Effect of Balanced Biaxial Stretching on the Low Cycle Fatigue Behavior of SAE 1008 Hot Rolled Low Carbon Steel. T. E. Parker and G. L. Montgomery, R & D Dept., Steel Co. of Canada, Ltd.

The effect of prestraining on the tensile properties and uniaxial low cycle fatigue behavior of SAE 1008 hot rolled low carbon steel strip has been investigated using a prestraining technique which simulates a press forming operation. Preliminary data for the case of a 40% balanced biaxial prestrain show a considerable increase in fatigue resistance in the long life regime. The reduced ductility as a result of prestraining, however, causes degradation of the short life fatigue resistance. Therefore, for component operation in the long life regime where the strains are mainly elastic, SAE 1008 may have considerably greater fatigue resistance than a designer would anticipate based on the yield and ultimate strength levels or fatigue data of the as-received material.

1975 SAE Transactions

750049. A Triaxial Automotive Wheel Force and Moment Transducer. R. S. Shoberg, GSE, Inc.; and Baird Wallace, Ford Motor Co.

A transducer capable of simultaneously measuring the dynamic forces and moments acting on the front or rear wheel of an automotive vehicle has been jointly developed by Ford Motor Company and GSE, Inc. This transducer was designed to be used on passenger cars with 13, 14, or 15 in wheels. It is adaptable to laboratory wheel and tire testing machines. An instrumentation package that provides electrical excitation, signal conditioning, and cross-talk compensation for the transducer was also developed.

The operational features of the transducer and the transducer instrumentation package as well as an assessment of some of its applications will be presented using functional block diagrams. Specifications for the system are listed and calibration data and road evaluation data will also be presented.

1975 SAE Transactions

750050. The Effect of Carburizing Variables on Residual Stresses in Hardened Chromium Steel. Morito Motoyama, Central Engineering Laboratories, Div., Nissan Motor Co., Ltd. (Japan); R. E. Ricklefs, Caterpillar Tractor Co.; and J. A. Larson, Ford Motor Co.

By calculating the cooling rate during quenching and calculating Ms temperatures from measured carbon contents and carbide quantities in depth, curves indicating the time at which transformation began in cylindrical specimens were determined. Using these curves, measured residual stress distributions were analyzed. Transformation started at a depth near the carburized case-core boundary, determined by the carbon gradient and cooling rate. It then proceeded out to the case and into the core, generating high internal stresses in these areas. The sequence of transformation was responsible for oscillations in the final residual stress distribution, with maximum compression occurring outside the case-core boundary.

Discussion: A. J. Titus, Ford Motor Co.

1975 SAE Transactions

750051. Design and Special Development Problems of Mercedes-Benz V-8 Engines. Kurt Obländer and Bertold Mayr, Daimler-Benz A.G. (Germany).

This paper discusses the Mercedes-Benz V-8 engines, their design as compared to US V-8 engines, and development concerning exhaust emission control and fuel consumption. Also covered are special problem areas, and their respective solutions which today have come to be of secondary importance, for example, the lubrication system, defoaming of the lubricant, noises generated by the lubrication system, and the adaptation of the hydraulic valve clearance adjustment to high engine speeds.

750052. Friction Losses in Automotive Plain Bearings: A

Practical and Theoretical Study. P. E. Vickery, Vandervell Products Ltd. (United Kingdom).
The power absorbed in the plain bearings of a small gasoline engine has been measured as a proportion of the total power lost to mechanical inefficiencies in the engine. A calculation procedure is described, by which means viscous friction in a plain bearing may be estimated. It is observed, that whilst the losses in plain bearings are small when compared to the other mechanical inefficiencies, they do represent an area where certain improvements are possible.

750053. The Influence of Transient Conditions on the Operation of an SI Engine, Especially with Respect to Exhaust Emissions. K. Zeilinger and A. W. Hussmann, Tech. Univ. Munich (Germany).
Engines of passenger cars operate almost exclusively under transient conditions. However, all influencing parameters are tailored to steady-state operation. An experimental investigation was made to determine if the correlations between emissions and engine operation on the one hand and on the other hand, the influencing parameters which are well known for steady-state conditions are valid also for transient operation.

The basic concept of the investigations and the experimental setup are described briefly. The results show clearly the differences between steady-state and transient operation, which are mainly caused by temperature effects.

750054. The Effects of Charge Dilution on Combustion and Its Improvement—Flame Photograph Study. K. Nakanishi, T. Hirano and T. Inoue, Toyota Motor Co., Ltd. (Japan); and S. Ohigashi, University of Kyoto (Japan).
The adverse effects of charge dilution on combustion of spark ignition engines are well known; as a tool for reduction of nitrogen oxide emission, it becomes important.

Some methods of analyzing combustion phenomena in a single-cylinder engine (27.1 CID) with charge dilution were tried. Multiple ionization probes roughly indicate the pattern of flame propagation, but details of the flame, especially charge dilution, cannot be measured by this method. Flame photographs, on the other hand, showed clearly the effects of combustion chamber design on flame propagation and its cyclic dispersion. The effects of combustion chamber configuration, ignition energy and spark duration, ignition timing, composition of diluent gas, air-fuel ratio, and mixture homogeneity were examined. Mass burnt fraction was calculated from both flame photographs and pressure indicator diagrams.

A combustion chamber having high turbulence and a rich air-fuel ratio promoted the initial flame propagation and flame speed and improved cyclic dispersion.

For high turbulence design, the combustion chamber of the commercial 97.5 CID, 4-cyl engine was modified. Fluctuation of output torque was measured and analyzed by correlation and probability analyses. This analysis indicated that high turbulence design was effective for improvement of car surge caused by EGR, and this was confirmed by actual driving on the road.

1975 SAE Transactions

750059. High Performance Ignition Components with Celanex Thermoplastic Polyesters. Allan G. Serle, Celanese Plastics Co.
Increasing demands on product performance, coupled with increasing emphasis on product reliability and safety, have made many conventionally-used materials virtually obsolete for automotive under-the-hood service. Celanex thermoplastic polyester, an injection-moldable engineering resin, has found, and is continuing to find application in new high performance automotive ignition components, where it is providing improved properties at reduced costs.

This paper reviews the properties and processing characteristics of this unique material as it relates to ignition component requirements, and discusses part design and tool design parameters necessary for obtaining optimum results. A number of ignition components currently in commercial production in glass fiber reinforced Celanex are illustrated, and details are given of some of the testing which preceded the commercial acceptance of the parts. Data is included on the material's performance in a new dielectric durability test, a special long-term test devised specifically to determine the material's capabilities in automotive ignition system service. Test data is also presented to show the superiority of the material over phenolic and alkyd resins in ignition system components.

750061. The Growth of Stampable Thermoplastic Sheet in Automotive Applications. Clifford E. Hale, Butler Metal Products.
The stamping of thermoplastic sheet is gaining acceptance in the automobile industry. The process has been used in consumer product areas which are less demanding than automotive, but this has demonstrated process viability. As the process gains in acceptance, special materials are being developed for stamping of components which have properties required for specific applications. There are several variations of the basic process as related to the product, material, and equipment. The definite advantage of stamping is rapid cycle time. In-the-mold decorating and pre-decorated materials will provide further applications in trim components. Stamping of termoplastic provides an additional tool for automotive engineers.

750063. Boss-Fastener Strengths with SMC Materials. W. H. Englehart, International Harvester Co.; and C. S. Richter, Owens/Corning Fiberglas Corp.
This paper will present the results of a boss testing program undertaken by International Harvester Company and Owens/Corning Fiberglas. The program represents

an initial step to determine boss strengths possible with low profile sheet molding compound (SMC) and to assess the dependence of strength on boss configuration, material composition, and fastener type.

With the multitude of available fastener thread types and the wide variation of possible boss configurations, only a limited selection of variables could be evaluated. The study looks at Hi-Lo and BT thread fasteners in various lengths. The effects of gussets and fillets on boss strength are shown over a range of glass contents. Material properties of the different laminate compositions are compared with the boss strengths from each material.

This information should serve as a basic guideline of boss strengths and as a groundwork for improvement of current design philosophy to optimize boss performance. The direction for further appraisals of boss performance, including improved designs and fatigue studies, will also be discussed.

750064. Correlation Tests in a Climatic Wind-Tunnel. B. Hamsten and F. M. Christensen, AB Volvo.

The report illustrates the first steps of full-scale aerodynamic correlation tests in the Volvo Climatic Wind-Tunnel and the knowledge achieved, applied to every day testing.

The scale model testing reported is a summary of the efforts involved trying to convert the climatic tunnel to an acceptable aerodynamic test facility. The aerodynamic activities in the tunnel take up less than 10% of available testing time, the main activity will still be climatic testing. Consequently, the investments involved must be considered according to this, and required accuracy must be set to match costs. The aerodynamic insert also has to be easy to install and remove due to high tunnel time utilization costs.

To make it easier for the reader of this report to understand the function of the facility, a short introduction of non-aerodynamic data has been included. Quality data for full-scale operation and aerodynamic performance are followed by reports of full-scale testing. The purpose of these tests has been to establish correlation in the sense of setpoint curves and accuracy limits.

For the scale model test insert, measurements of flow quality and investigating tests with passenger car models are reported.

Another important and helpful part of practical aerodynamics, flow visualization, has not been included. The work in this field has been intense both in full-scale and model work, but the experiences achieved have been considered basic.

750065. Correlation of Pressure Measurements in Model and Full-Scale Wind Tunnels and on the Road. G. W. Carr, Motor Industry Research Association.

A three-way correlation study of aerodynamic pressure measurements has been carried out between the MIRA model and full-scale wind tunnels and actual road conditions. Six vehicles and two quarter-scale models were used, each fitted with 30 or more static pressure tubes and tappings connected to a multi-tube manometer. The results showed close correlation between full-scale tunnel and road measurements, though apparently with a smaller blockage effect than previously assumed. Good correlation was also found between model and full-scale tunnel measurements, provided a high standard of accuracy was maintained in the model manufacture.

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750066. The Wind Tunnel's Ground Plane Boundary Layer - Its Interference with the Flow Underneath Cars. W. H. Hucho, L. J. Janssen and G. Schwartz, Volkswagenwerk AG (Germany).

In order to determine the best way to simulate a road in the full-scale climatic wind tunnel of the Volkswagenwerk AG, a series of comparative tests between road and tunnel have been carried out. In general, a good correlation was achieved when a rigid ground plane was used for road simulation. Only a small margin for improvement by boundary-layer control remains. From measurements reported in the literature, it can be seen that an effective reduction of the boundary-layer displacement thickness of 60% can be achieved with single-slot suction. Nevertheless, this would result in a hardly noticeable improvement of test-data correlation for cars with standard ground clearance. Therefore, it was decided not to install a boundary-layer suction in the wind tunnel of Volkswagenwerk AG.

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750067. A Survey of Automotive Rankine Cycle Combustion Technology. S. Luchter, U.S. Environmental Protection Agency; and W. Mirsky, University of Michigan.

The Rankine cycle engine is being considered as an alternative to the emission controlled spark ignition automobile engine, primarily because of the promise of inherently low emissions. Much of this promise is beginning to become reality. The development of combustors for Rankine cycle engines has progressed to the point where very low steady state emissions have been demonstrated for several combustor designs. In addition, the original 1976 emissions standards have been met in several motor vehicles powered with Rankine cycle powerplants.

750068. Component Development of Automotive Reciprocating Steam Expanders. Stanislav Jakuba and James A. McGeehan, Scientific Energy Systems Corp.

The Closed Rankine cycle steam powerplant is currently being re-examined as a low exhaust emission alternative to a gasoline spark ignition engine for use in automobiles and other vehicles. The paper summarizes the progress to date on the reciprocating steam expander component

development program sponsored by U.S. Environmental Protection Agency under EPA Contract 68-04-0004. The principal components reviewed are: pistons, ring/liner combinations, valve train, series poppet valves for variable admission of steam to the cylinders and recompression steam relief valve. The current state-of-the-art of automotive technology was used in component development work. Temperature and pressure measurement techniques are also described.

750069. Experience with Steam Cars in California. Roy A. Renner, Livermore, Calif.; and Michael Wenstrom, California Research.

The California Legislature conducted an investigation into the low emission properties of steam-powered automobiles, 1972-74. Two steam propulsion systems were built and installed into sub-compact cars suitable for urban driving. The Aerojet Liquid Rocket Co. installed a steam turbine in a Chevrolet Vega, while Steam Power Systems built a piston engine system for a car of special design. The project demonstrated that it is possible to reduce exhaust emission levels to less than those required by the 1978 Federal standards. Road performance was adequate for urban-suburban driving. Fuel consumption was higher than comparable internal combustion-powered vehicles. Guidelines for future improvements are given.

750070. Steam Power Systems' California Clean Car Project. Philip H. Schneider, Steam Power Systems, Inc.

A low-pollution steam-powered automobile using a reciprocating piston expander was built and tested for the California Clean Car Project. The performance test results of the automobile and the powerplant are presented herein. The primary test goals which have been successfully demonstrated with the current vehicle are low exhaust emissions and low noise levels. Areas that require improvement in a next-generation vehicle include fuel economy, acceleration, power, reliability, and start-up time. Plans for improving the vehicle powerplant are discussed briefly.

750071. The Carter System—A New Approach for a Steam Powered Automobile. Jay W. Carter, Jr., Jay Carter Enterprises, Inc.

A steam powered Volkswagen has been tested by the Environmental Protection Agency and meets the strict 1977 emission levels without the use of add-on emission control devices. The steam system is unusual in its use of high pressure (up to 2500 psi), high temperature steam (1100°F) in conjunction with a high speed reciprocating expander (up to 6000 rpm), constant expansion ratio, variable pressure boiler, and a conventional automotive transmission to achieve an extremely compact design of high thermal efficiency.

750072. A Review of Successful Fuel Conservation Measures for Motor Vehicle Fleets. S. E. Swallow, Ford Motor Co. of Canada, Ltd.

Normal means of reducing vehicle fuel consumption, such as lower speeds, shorter trips and proper maintenance, are well known. This paper reviews a number of other, lesser known, fuel conservation measures this paper includes practical recommendations for their application and cites results that may be achieved.

750074. Use of Natural Gas as a Primary Vehicular Fuel for a Public Utility Fleet. William G. Goninan, Southern California Gas Co.

One public utility has converted over one-half their fleet to a dual fuel operation using natural gas as the primary fuel and gasoline as an alternate. They report that conversion to natural gas can be accomplished with minimum change in administrative maintenance practices.

Fuel costs are reduced significantly. Vehicle maintenance costs are essentially the same as with straight gasoline operation. There is some indication of prolonged engine life which may permit extension of the useful life of the vehicles. The ability to operate vehicles on either of two different fuels provides added flexibility in maintaining service to public utility customers during periods when one or the other type fuel is in short supply.

750075. The Electric Multistop Fleet Delivery Vehicle —Fact or Fantasy. Paul R. Hafer, Battronic Truck Corp. and Boyertown Auto Body Works; Arthur Dicker, Jr. and Harry D. Yoder, Battronic Truck Corp.

The purpose of this presentation is to alert the fleet delivery vehicle owners and operators of the facts relating to the performance breakthrough achieved by the Electric Vehicle Council's (EVC) work vehicle. Their declared desire to advance the state-of-the-art by a factor of two has actually been exceeded. The 108 vehicles now in operation throughout the United States and Canada are proving with factual costs—energy consumption, freeway speed, and distance performance records that the energy storage battery powered fleet delivery vehicle is indeed a present day fact! These records forecast actual savings in fuel energy costs that add up to substantial savings when compared accurately with the increased gas and/or diesel fuels consumed by the multistop fleet delivery vehicles now available with 1975 EPA pollution control devices. It is a little recognized fact that the EPA standards call for these devices to function properly with nominal engine idling time while stopped for 10% of the driving cycle, whereas the majority of multistop fleet delivery vehicles operate with nominal engine idling time of 50% or greater during their traffic and work route driving cycle. The impact of the increased first cost for these pollution control devices, plus the increased fuel cost, and much higher service and maintenance costs should cause fleet operators to examine the facts presented herein about the family of electric multistop fleet delivery vehicles available now. The potential for cost and energy savings are real and substantial. They can now make great contributions

to combat inflation and conserve fossil fuels by the more efficient use of electric energy that can be stored in the vehicle batteries during off peak generating periods. They can now be used with substantial increase in non-polluting efficiency in the multistop fleet delivery vehicles in our sprawling megalopolis areas.

750076. Comparison of Three Types of Front Body Construction of Sub-Compact Cars. Akihiro Wada and Masahiko Inove, Toyota Motor Co.

Three different types of front suspension and the corresponding body construction configurations were selected for comparison among unitary constructed subcompact cars with a weight range between 2,500 lb and 3,000 lb and which are currently being manufactured by Toyota. These were compared and evaluated in terms of weight, productivity, noise and vibration characteristics, and crashworthiness. The pros and cons of each type were analyzed and the results of this analysis are presented in this paper.

From these results, it has been concluded that when only the front body is considered, these three types of front body design are preferable in the following order:

1. McPherson type.
2. Double wishbone type with upper and lower arms installed on the fender apron.
3. Double wishbone type with upper and lower arms mounted on the suspension member.

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750077. Automotive Structural Bonding. R. H. Beck, Jr., Ford Motor Co.; and D. A. Yurek, 3-M Co.

This paper is a general review of automotive structural adhesive bonding. Advantages and disadvantages of structural bonding are reviewed, and adhesive requirements peculiar to the automotive industry are noted. The three most common automotive structural adhesives are described, and adhesive testing, in both laboratory and in production facilities, is discussed. Three examples of automotive structural bonding in Ford Motor Company are outlined.

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750078. Use of Dynamic Modeling and Analysis to Cure Ride Quality Problems. Timothy R. Sisson and Garth H. Wiley, Structural Dynamics Research Corp.

A very straightforward procedure for solving ride quality problems is discussed. This procedure utilizes advanced dynamic testing and system modeling techniques in a logical three-step sequence. The first step is to define the nature of the problem through measurement of data during operation of the vehicle. The second step involves the measurement of vehicle dynamic characteristics such as resonant frequencies and mode shapes through controlled lab tests. This information is compared with the operating data to identify structural features which contribute to the ride problem.

The last step is to assemble a dynamic computer model of the vehicle which can be used to quickly evaluate proposed solutions to the problem.

Two examples are given which serve to demonstrate the effectiveness of this approach.

750079. Caterpillar's New Sleeve Metering Fuel Injection Systems. Richard A. DeKeyser, Marvin A. Gates and John H. Parks, Caterpillar Tractor Co.

Caterpillar's new Sleeve Metering Fuel Injection System comprises a family of lightweight, high speed injection pumps designed to serve the present and future medium horsepower truck, industrial, and captive vehicle needs. The fuel lubricated pump and governor combines some new innovative design features with proven individual pump durability advantages.

The paper discusses the design, development, and test program, and some of the results obtained. Modern manufacturing methods and computerized testing were an integral part of the total system development.

750080. A Simplified Approach to Flow Network Analysis: Application to Engine Lubrication Systems. Kenneth H. Huebner, General Motors Corp.

The nature of general flow network problems is discussed, and nonlinear programming techniques are suggested as an especially expedient method of solution. In particular, the computer coding for Rosenbrock's algorithm is given, along with step-by-step instructions for its use in analyzing arbitrary flow networks. Application of the solution technique to the analysis of an engine lubrication system is also presented.

750084. Borg-Warner Automatic Transmissions Model 45 and Model 55. John S. Ivey, Borg-Warner Corp.

A brief discussion of the Borg-Warner M-45 (four-speed) and M-55 (three-speed) automatic transmissions for passenger cars follows. Detailed pictures and cross-sections are presented which emphasize the advantages of designing these components of steel stampings for production on multiple station transfer presses.

750086. A Review of Philosophical Considerations in the Development of Radar Brake Systems. R. A. Chandler and L. E. Wood, U.S. Dept. of Commerce; and W. A. Lemeshewsky, U.S. Dept. of Transportation.

The National Highway Traffic Safety Administration (NHTSA) has been involved in an investigation into the economic and technical feasibility of applying radar devices as sensors for automatic braking systems. Several different system application philosophies have been defined and discussed with consideration being given to the expected economic and safety benefits afforded by each.

The technical feasibility study, performed for NHTSA by the Institute for Telecommunication Sciences of the

U.S. Department of Commerce, included such topics as radiation hazards, intersystem blinding effects, performance restrictions imposed by common highway geometries, effects of precipitation on signal propagation, and analysis of vehicular radar cross sections.

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750087. Dual-Mode Automobile Collision Avoidance Radar. G. S. Kaplan and F. Sterzer, RCA Corp.

A dual-mode (cooperative and non-cooperative) collision avoidance radar is proposed. The cooperative mode of the radar is based on tagging cooperating vehicles and other potential highway hazards with modulated fundamental frequency reflectors. The range of the radar when looking at tagged targets is approximately 100 metres. Targets that do not carry tags are also recognized by the radar. However, in order to minimize the "false target" problem, the range of the non-cooperating mode of the radar is restricted to a few metres.

750088. Automobile Radar Signature Studies. Robert M. Storwick and Louis L. Nagy, Research Laboratories, General Motors Corp.

One of the prime requisites for automobile radar systems is obstacle hazard evaluation, the extent needed being dependent upon the particular system application. Much of the information necessary for a radar system to assess the degree of hazard of a target must come from characteristics which can be measured by the radar itself. While the hazard evaluation capacity has not yet been developed for automobile radar systems, research to provide this capability is in progress.

Continuous wave (CW) scattering measurements have been made in a manner which is consistent with automobile radar operation. Various aspects of simple targets and of an automobile were measured in a microwave anechoic chamber. Both horizontal and vertical linear polarizations were transmitted and their co-linear and cross polarizations received.

These data have been used to confirm the existence of and to understand certain scattering mechanisms. They have also been subjected to analyses in order to determine the ability to discriminate among the various simple targets. It is demonstrated that even a simple analytical method shows discrimination capability among the targets tested. Other techniques have been used in attempting to discern important features of these targets.

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750089. Binaural Automobile Radar. Mark K. Krage, Research Laboratories, General Motors Corp.

The antenna configuration of a radar crash sensor determines in large part the kinematic measuring capabilities of such a sensor. Simple monostatic and bistatic antennas have limited collision estimation abilities which can potentially be overcome by a binaural system. The theoretical characteristics of a binaural radar have been used to optimize the collision estimation abilities for point target obstacles. Measurements with obstacles of small lateral extent are in good agreement with theory. Measurements with obstacles of large lateral extent do not agree with simple point target theory due to detection of different scattering centers by the two bistatic arrays of the binaural radar. Methods of minimizing this problem are discussed.

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750090. Sulfate Emissions from Catalyst Cars: A Review. Ronald L. Bradow and John B. Moran, United States Environmental Protection Agency.

A review of the available data on sulfate emissions methods and emissions rates from both catalyst-equipped and non-catalyst cars has been made. Air-dilution methods of various sorts appear to give similar sulfates emissions results, comparable with those obtained by controlled condensation procedures. Mobile source SO_2 measurements technology requires much more attention. At present, only the hydrogen peroxide oxidation to sulfate has been demonstrated to give reliable results. Summaries of several hundred catalyst and non-catalyst emission rates are treated to estimate California and 49-state emissions. A cruise-mode emission rate of about 0.03 g/mile appears appropriate for both monolithic and pelleted catalysts in 49-state cars.

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750091. Sulfuric Acid and Nitrate Emissions from Oxidation Catalysts. David A. Trayser, Ellsworth R. Blosser and Fredrick A. Creswick, Battelle Columbus Labs.; and William R. Pierson, Scientific Res. Staff, Ford Motor Co.

The authors have investigated the emission of sulfuric acid and nitrates from a 1973 Ford 351C V-8 engine equipped with prototype 1975 emission controls and mounted on a dynamometer test stand. Tests were performed on unleaded fuel at 60 mph road-load conditions, using monolithic noble-metal catalysts and no catalyst, and at 60 and 30 mph road-load conditions using a pellet-bed noble-metal catalyst.

Sampling for SO_2 and H_2SO_4/SO_3 measurement was effected at several points within the exhaust system as well as from a dilution tunnel where the exhaust was diluted ten-fold with filtered air. Samples collected in the dilution tunnel were analyzed for total particulate mass, sulfate, condensed water, and pH. Ammonia injection into the dilution tunnel on selected runs permitted collection of nitrate and HNO_3 on the filters as NH_4NO_3.

Nearly all of the fuel sulfur was emitted as SO_2, and less than 1% as sulfate, in the absence of a catalyst. With the catalyst, about 43% of the emitted sulfur was in the form of sulfate at 60 mph (monolith or pellet), and 86% at 30 mph (pellet catalyst). Sulfate storage in the monolithic catalyst at 60 mph road load was negligible. Some sulfate storage was noted in the pellet-bed catalyst at 60 mph road load. Afterwards, substantial storage occurred in the pellets at 30 mph; the storage rate was $>50\%$ of the sulfur

consumed during the first 2 h of 30 mph operation; with further cumulative storage the storage rate declined to ~15% of the consumption rate after 1000 miles at 30 mph, at which time the pellets contained 3% sulfate. Catalyst-produced particulate emissions were composed almost entirely of sulfuric acid and associated water. About 95% of the H_2SO_4 mass (with catalyst) was composed of droplets of less than 0.3 μm aerodynamic diameter. The amount of nitrate present in the engine exhaust was very low (≲300 μg/mi), and was not perceptibly enhanced by the presence of a catalyst.

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750092. The Low-Sulfur Unleaded Gasoline Problem. Ronald G. Bruce, Continental Oil Co.

It has been reported that automobile exhaust resulting from gasoline containing sulfur can produce a potentially harmful sulfuric acid mist when passed through an oxidation catalytic converter. In response to an Environmental Protection Agency (EPA) request, the National Petroleum Refiners Association conducted an industry survey to develop information concerning the impact of reducing the sulfur in unleaded gasoline to a maximum of 100 ppm. The survey showed that an estimated 361 new processing units would be needed at a cost of $3.7 billion. It further pointed out that it was probably beyond the capability of the already overloaded engineering/construction industry to complete such facilities within three years.

750093. Hydrogen Sulfide Formation Over Automotive Oxidation Catalysts. Gerald J. Barnes and Jack C. Summers, Research Labs., General Motors Corp.

A number of laboratory and engine dynamometer studies were conducted to determine the effect of various catalyst and engine operating parameters on the formation of H_2S over alumina-supported Pt and Pd catalysts.

These experiments indicate that H_2S formation occurs at high temperatures under O_2 deficient conditions. The fraction of exhaust gas SO_2 converted to H_2S was relatively constant for various fuel sulfur levels, and thus H_2S formation decreases as fuel sulfur content decreases. Calculation of thermodynamic equilibria, as well as various experimental results, indicate that H_2S formation is kinetically limited under the experimental conditions investigated.

Since the operating conditions that favor H_2S formation (high catalyst temperature and O_2 deficiency) do not normally occur in current oxidation catalytic emission control system operation, the formation of H_2S over automotive oxidation catalysts is unlikely unless engine or system malfunctions occur.

Discussion: William R. Pierson, Scientific Research Staff, Ford Motor Co.

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750094. Miniature Probes for Use in Gas Turbine Testing. George E. Glawe and Lloyd N. Krause, Lewis Research Center, NASA.

Because of space limitations and system complexity in many applications associated with gas turbine testing, extremely small flow measuring probes have sometimes been required. This paper presents several examples of these miniature probes—null type as well as fixed position—which have proved useful in aircraft and space power systems component testing and are applicable to automotive gas turbine testing. These probes are used to determine component or system performance from the measurement of gas termperature as well as total and static pressure, and flow direction. Detailed drawings of the sensors are presented along with experimental data covering the flow characteristics over the range of intended use.

750095. The Conversion of SO_2 Over Automotive Oxidation Catalysts. M. Beltzer, R. J. Campion, J. Harlan and A. M. Hochhauser

Noble metal oxidation catalysts have been shown to convert gasoline sulfur to automotive particulate sulfate emissions. A study was carried out in a laboratory bench scale reactor to evaluate the effect of vehicle operating conditions and catalyst type on the conversion of SO_2 to SO_3. The factors studied included catalyst temperature, exhaust gas 0_2 content and space velocity. The results are compared with data from a vehicular study designed to assess total sulfur emissions from catalyst-equipped cars.

This study indicates that control of exhaust sulfate emissions may be achieved through close control of the oxygen content of exhaust gas and that the choice of catalyst affects the degree of conversion of SO_2 to SO_3 and the amount of oxidized sulfur retained in the catalyst system.

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750096. Effect of Three Way Conversion Catalyst Operation on the Chemical State of Automotive Sulfur Emissions. J. G. Cohn, W. A. Mannion and C. E. Thompson, Englehard Industries Division, Engelhard Minerals & Chemicals Corp.; and J. G. Hansel, Engelhard Industries Division, Engelhard Minerals & Chemicals Corp.

Emission of SO_3 or of sulfates can be virtually eliminated from catalytically controlled vehicles by operation in three way conversion mode as well as by operation of oxidation catalysts without air pumps. Hydrogen sulfide is not detected during normal excursions into the rich air-fuel region.

Combined with the fact demonstrated by Volvo that vehicles equipped with Engelhard three way conversion catalysts meet or are lower than the 1975-76 California emission standards after 50,000 miles of driving, a viable solution exists for emission control of all pollutants including sulfates.

750097. Some Phenomena Which Control Sulfuric Acid

Emission from Automotive Catalysts. Robert H. Hammerle and Mati Mikkor, Ford Motor Co.

With the use of a simulated exhaust system, the sulfuric acid and sulfur dioxide emission from a monolith noble-metal oxidation catalyst (Engelhard IIB) is measured. It was found that the storage rate of sulfur onto an initially sulfur-free catalyst decreases to a few percent of the sulfur rejection rate within 3–4 h. The amount of sulfur on the catalyst when the catalyst is in equilibrium with 20 ppm sulfur in the gas phase varies between 0.3 weight percent of the catalyst at about 400° C to 0.1 weight percent at 600° C. The sulfur can readily desorb from the catalyst if the gas phase sulfur content is lowered or if the catalyst temperature is increased.

It was found that the conversion of sulfur dioxide to sulfuric acid reaches thermodynamic equilibrium at temperatures of 400–500° C and space velocities of 30,000 h^{-1}. These conditions correspond approximately to a small V8 engine at 20 mph cruise.

In the simulated exhaust system without a catalyst, propylene, propane and hydrogen, which are present in automobile exhaust, reduce sulfuric acid to sulfur dioxide. This reduction appears to be a homogeneous reaction.

750098. Steel Capacity and Critical Raw Materials: an Outlook for Growth. Albert W. Connar, Bethlehem Steel Corp.

A presentation on domestic steel production, both current and estimated for 1980. Focus is primarily on need for increased capacity and projections of availability of essential raw materials that may hinder or delay expansion. Included are outlooks for iron ore, zinc, nickel, ferro alloys, refractories, electrodes, fossil fuels, electric power and ferrous scrap.

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750099. Nonferrous Resources—A Five-Year View. James M. Owens and Emil A. Romagnoli, United States Dept. of Commerce.

The purpose of this paper is to discuss the availability of both resources and industry capacity for certain nonferrous metals that will be required by the automotive industry through 1980.

Because of the complexity of the issues involved, it will be necessary to examine some of the basic problems that have been affecting resources availability and metal capacity, as well as those problems which are expected to be troublesome in the 1975–1980 period. Although the scope of the paper is supply availability, it will also be necessary to consider demand, particularly demand by the automotive industry, in the attempt to relate materials requirements to availability. Emphasis is placed on copper, zinc, and lead, with attempts at examining exploration; development; and capacity at mine, smelter, and refinery stages in an effort to pinpoint potential bottlenecks in supply flows.

750100. Ferrous Foundry Industry Long-Range Outlook for Raw Materials. George A. Watson, Ferroalloys Association.

Over the past year or so there has been a short supply of materials for the ferrous castings industry. Raw materials and energy are important natural resources which must be conserved carefully and by cooperative efforts to insure that we have enough to supply our future needs. Materials serve functional needs of man, and man must therefore be conscious of the amount of material, energy, and labor necessary to produce a given product so that waste of materials and thus depletion of the sources for the manufacture of future products can be avoided. Recycling raw materials, resource diplomacy, and maintaining an adequate data base of information are important measures for energy and raw materials conservation.

The real problem for the automotive industry and its need for ferrous castings is not only the inadequate supply of raw materials but the lack of sufficient foundry capacity to meet the demand for castings as a result of pollution control laws and low profitability. The challenges of reaching a balance among these factors must be met for the survival of the automotive industry.

750101. The Impact of the Energy and Materials Resource Problems on Powder Metallurgy. Kempton H. Roll, Metal Powder Industries Federation.

Before the rise of "stagflation" as the catchword of the times, American industry was struggling with another: "Energy." Ecology and environmental protection also achieved stardom with the populace, aided considerably by the media. But "materials resources" or lack thereof has not succeeded in gaining this kind of public attention. "So what if we have only a 30-day supply of chromium? Automobiles could do with less gaudy trim anyway," seemed to be the general attitude. Industry, however, especially the metalworking industry, has become well aware of the materials problem this nation is facing and the fact that it is indeed a real problem. Industry is also painfully aware of the other problems—ecology, environmental protection, energy conservation, and so on —because it too often finds itself being blamed as the cause.

750106. Aiding Mini-Computer Applications with a Problem-Oriented Language. Norman R. Lewis and Gary J. Rutledge, General Motors Technical Center.

Many mini-computer applications are never implemented due to the shortage of skilled programmers. A high level programming language enabling non-programming personnel to do application programming is a possible solution to this problem. This paper covers G.M.'s experience in creating and implementing a problem-oriented language.

750108. An Inter-Laboratory Comparison of Olsen Cup Values on Aluminum Base Alloys. B. S. Shabel, Alcoa Laboratories.

A discussion is presented involving a program in which five aluminum companies set about to determine the variability of Olsen cup height measurements. Samples of 0.04 in thick AU2G-T4, 2036-T4, 3004-0, 5182-0, 5056-Hill, X5085-Hill, 6151-T4, and P48.3 were used. Lubrication and speed variation were found to affect the average Olsen values.

Results indicated that the highest Olsen values were obtained using polyethylene film lubrication and a punch speed of 3 in/min. The conclusion was reached that reliable Olsen values could be obtained if the testing conditions were sufficiently standardized and reproducible.

750110. Vehicle to Vehicle Collisions Utilizing Energy Absorbing Units. R. M. Krupka and A. B. Krueger, Chrysler Corp.

This paper presents the possibility of utilizing shock absorbers to decrease the aggressivity of a large car towards a small car at an impact of 40 mph. Reduction of such aggressivity would result in more damage to the large car, thereby reducing the impact on the small car.

The conclusions demonstrate a definite decreased aggressivity of the larger car. Increase of the shock stroke does cause the large car to be crushed more in car-to-car collision. However, this occured at speeds below 25 mph, not the 40 mph as set by the study.

750111. Decorative Plating of Aluminum for Car and Truck Exterior Component Parts. R. V. Paulson, Kaiser Aluminum.

This paper presents a comparison of plated aluminum and plated steel for use in exterior component parts of cars and trucks. The conclusions reached by this comparison show that:

1. Plated aluminum will be more attractive and as servicable as plated steel when correctly processed.
2. It enhances the appearance of aluminum components.
3. It coordinates aluminum components with other plated parts.
4. It retains its good looks much longer and has better corrosion resistance.
5. Using M&T's Alstan 80 production system, the cost of plating aluminum sheet or plate costs essentially the same as plating steel.

750113. Large and Small Car Accident Performance: A Large Scale Accident Data Base Analysis. Basil Y. Scott, New York State Dept. of Motor Vehicles.

New York State's development of a system for examining the relationship between vehicle design and traffic crash incidence and injury severity made possible a study of the relationship between small car and large car accident performance. Accident involved vehicles were studied using such variables as make, model year, shipping weight, horsepower, and accident data such as impact area, road conditions, and seat belt use. Considering these and other variables, occupants of the smaller cars experienced higher rates of injury severity in crashes than occupants of larger cars.

750114. Compatibility Between Big and Little Cars. Jerome M. Kossar, Natl. Highway Traffic Safety Admin., U.S. Dept. of Transportation.

Hybrid front end car design provides a straight forward approach to achievement of compatibility during crashes between the smallest and largest cars as well as all other sizes between. Compatibility means optimal conditions for occupant survival in frontal, side and rear collisions through a broad range of closure speeds and potential obliquities.

Hybrid front ends consist of designs producing primary load paths through short stroke, self force regulating hydraulic cylinders in series with crushable structure. Conservative analytic approach demonstrates compatibility in head-on closures of at least 70 mph between a 1500 lb car and any other heavier car. This compatibility is attained with only a $29\frac{1}{2}$ in crush of the small car.

750115. The Role of Vehicle Handling in Accident Causation. Ian S. Jones, Calspan Corp.

This paper reports the results of a study designed to investigate the relation between vehicle handling and accident frequency. Because evaluation of the driver control process can only be made on a subjective basis, emphasis is placed on evaluating the role of the vehicle rather than the man-car combination.

Deficiencies in handling are likely to be associated with accidents involving loss of control, and it is shown that over 80% of loss of control accidents involve single vehicles only. This means that the single vehicle accident rate can be used as a measure of proneness of loss of control. Single vehicle accident rates are determined by model of car and the effect on these rates of other factors, such as variations in driver age and ratio of male to female driver population between the different models, are assessed. This allows accident rates to be established which are, to a large extent, independent of driver effects, so that their relation with vehicle handling performance can be directly assessed.

In selecting parameters with which to evaluate the role of the vehicle, emphasis is placed on simplicity of measurement to allow as many different models of car as possible to be included in the study. Accordingly, simple design parameters as well as more complex vehicle response parameters are considered.

Multiple regression techniques are used to establish the relative importance of handling response parameters when compared to driver effects and also to decide which are the most appropriate parameters to consider. The results show that in explaining the variation in the accident rate between different models of car, driver effects account for as much as 70%; if driver effects are

removed from the accident rate then handling parameters explain about 35–40% of the remaining variation between models of car. The important parameters appear to be weight, a measure of the change in understeer as a function of lateral acceleration and power to weight ratio.

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750116. How Much Safer Are You in a Large Car. James O'Day and Richard Kaplan, Highway Safety Research Inst., University of Michigan.

Two sources of data, one describing exposure and another describing fatal accidents, were used to estimate the national distribution of fatalities classified by four age groups and two vehicle size groups. The results show that the probability of receiving a fatal injury is greater in small cars than it is in large cars, and that the difference increases with age. This is true despite the fact that older drivers tend to be involved in less severe crashes. The reasons for these findings are discussed with particular attention given to injury patterns within different age groups.

750117. Effect of Vehicle Mix on Two-Car Head-On Impact. Kuang-Huei Lin, Mounir M. Kamal and J. William Justusson, Res. Labs., General Motors Corp.

The comparative dynamic response (acceleration, velocity, and crush) of two cars, differing in mass and structural characteristics and impacting head-on, is examined for various closing speeds and payloads through the use of a computer simulation model. Among other results, this analysis of the so-called vehicle mix problem shows the inherent limitations of "equivalent barrier impact" concepts in analyzing such impacts.

750118. Potential for Methanol as an Automotive Fuel. R. M. Tillman, O. L. Spilman and J. M. Beach, Continental Oil Co.

Multiple cyl engine tests demonstrated that lean methanol operation gave improved tail pipe emissions and better Btu efficiency than gasoline. The reductions in NO_x emissions were particularly significant. Some loss in maximum power output was experienced, but the loss was less than that for gasoline operation at equivalent NO_x emissions. This program was directed toward making the minimum number of engine modifications to simplify retrofitting of existing vehicles to utilize methanol.

750119. Single-Cylinder Engine Evaluation of Methanol —Improved Energy Economy and Reduced NO_x. W. J. Most and J. P. Longwell, Exxon Research and Engineering Co., Exxon Corp.

Comparative testing of pure methanol, methanol/water blends and isooctane in single-cylinder engines has demonstrated that through proper utilization of methanol's fuel-lean combustion characteristics it may be possible to reach CO emissions of the order of 0.1% and NO_x emission levels of less than 100 ppm in the raw (undiluted) exhaust. Exhaust treatment to remove unburned methanol and partial oxidation products might be required. Concomitant with decreased emissions are specific energy consumption improvements estimated to be in the range of 26–45% better than achievable with current gasolines and the associated low compression ratio engines and emission control systems. These energy consumption improvements are obtained by virtue of efficient lean operation and by utilizing the high octane values of methanol/water blends at high compression ratios. Despite these potential end-use technical advantages for methanol, its large scale use as an automotive fuel is precluded for at least one to two decades because of inadequate supply, the need for immense capital expenditures to increase supply and the need for special engine and fuel control designs.

Discussion: D. L. Hilden, F. B. Parks and R. F. Stebar, Research Labs., General Motors Corp.

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750120. Exhaust Emissions, Fuel Economy, and Driveability of Vehicles Fueled with Alcohol-Gasoline Blends. N. D. Brinkman and N. E. Gallopoulos, Fuels and Lubricants Department; and M. W. Jackson, General Motors Corp.

Current national interest in alternative fuels has placed considerable emphasis on alcohols, mainly methanol and its blends with gasoline. Vehicle studies with methanol-gasoline and ethanol-gasoline blends showed that adding alcohol to gasoline without carburetor modifications decreased carbon monoxide emissions, volume-based fuel economy, driveability, and performance. Depending on the carburetor's air-fuel ratio characteristics, hydrocarbon and nitrogen oxide emissions and road octane are either increased, decreased, or not affected.

These effects can be explained on the basis of changes in stoichiometry, energy content, combustion temperatures, and detonation resistance caused by the addition of alcohol to gasoline.

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750121. Methanol as Automotive Fuel, Part I - Straight Methanol. R. D. Fleming and T. W. Chamberlain, Energy Research and Development Administration.

A study of methanol as an automotive fuel was conducted using a single-cylinder research engine, a 4-cylinder 122-CID (2,000 cc) engine, and an 8-cylinder 350-CID engine. Results showed that when using methanol as fuel, the single-cylinder engine could operate leaner than the multicylinder engines. This difference is attributable to air-fuel mixture maldistribution associated with the multicylinder engines.

Steady-state fuel economy and emissions data are presented and discussed. Results indicate that fuel economy (on an energy input basis) using methanol fuel is about 5% improved as compared to gasoline fuel economy and with substantially lower nitrogen oxides emissions for methanol.

750123. Methanol as a Motor Fuel or a Gasoline Blending Component. J. C. Ingamells and R. H. Lindquist, Chevron Research Co.

Laboratory and road tests showed methanol to be an effective octane booster. Adding 10% methanol to unleaded gasoline raised the Road octane 2–3 numbers. However, significant deterioration in driveability tests occurred because of methanol's "leaning" effect. The water sensitivity of methanol/gasoline requires a separate fuel distribution system. Fuel storage in a vehicle must be protected from water absorption. Corrosion and degradation problems occur in the vehicle fuel system where methanol/gasoline mixtures contact lead, magnesium, aluminum, and some plastics. Methanol burned more efficiently under lean conditions than gasoline. However, the cold start problems require a separate starting fuel. Methanol is not a useful fuel additive for existing unmodified cars. Methanol could be used effectively in special vehicles designed to handle the corrosion, water absorption, and vaporization characteristics. The cost of manufacture and distribution in a separate system that overcomes the water sensitivity problem will determine the extent of methanol's use as a vehicular fuel.

Discussion: Carl O. Thomas, Inst. for Energy Analysis, Oak Ridge Associated Universities.

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750124. Racing Experiences with Methanol and Ethanol-Based Motor-Fuel Blends. T. Powell, Hofstra University.

Methanol and ethanol have interesting possibilities as motor fuels and have been used as such, mostly in blends, since the early days of the automobile. However, specialized experience with alcohols as high-performance racing fuels more or less parallels World War I era results with substitute motor fuels. These indicate several types of practical operational problems with water solubility, plastics solvent action, metal corrosion and galvanic effects, low air-fuel ratios and low calorific content, and high latent heat. Simply switching to alcohol-gasoline blends in conventional automotive fuel systems and engines is not as straightforward a matter as some short-term laboratory tests might tend to indicate.

Some of the modern-day racing techniques for handling alcohol fuels include: anodizing and plating of nonferrous alloy fuel system and engine castings; using solvent-resistant plastics and corrosion-resistant metals; draining and flushing out the fuel system and engine with hydrocarbon-fuel oil mixes after running; using alcohol-soluble synthetic lube oils; sealing and storage of fuel containers and tanks so as to reduce atmospheric moisture absorption; using higher-energy ignition systems to better fire the "wet" alcohol fuels at high C.R.'s; and nearly tripling and doubling the fuel system capacity.

750126. An Investigation of Integrated Retarder/Foundation Brake Systems for Commercial Vehicles. Rudolf Limpert, University of Utah.

Commercial vehicles such as buses and trucks operating on our highways today have brake systems designed to achieve acceptable levels of braking performance for both effectiveness stops and long downhill braking. Using foundation brakes alone, temperature limitations have resulted in heavy drum and brake assemblies. Basic engineering analysis reveals that hydrodynamic retarders can be designed to absorb nearly downhill braking energy in addition to up to 90% of the braking energy developed during a typical effectiveness stop. Integrated retarder/foundation brake systems allow significantly increased downhill traffic speeds, and decreased driver fatigue due to improved ease of vehicle control, and provide brakes that are essentially fade free during extended downhill operation. Vehicles thus equipped will exhibit three to four times longer brake lining life, lower maintenance costs, and vehicle down times, as well as higher operating speeds. Existing Federal Motor Vehicle Safety Standards need to be modified to include optional procedures for retarder equipped vehicles.

750128. (SP-391) The Diesel Engine for Truck Application. P. S. Myers, Mechanical Engineering Dept., University of Wisconsin.

Because of its outstanding fuel economy and its somewhat lower maintenance costs, the diesel engine has become dominant in the transportation field, especially for heavy-duty trucks. There is evidence that use of diesel engines in medium- and light-duty trucks as well as in passenger cars will increase in the future. Most diesel engines are installed in commercial vehicles. However if the engine is not carefully matched to the transmission and accessories, as well as to the specific vehicle application (severity of duty), the total package may be commercially unattractive.

The purpose of this paper is to detail the most important considerations in matching diesel engines with transmission, components, etc., for use in commercial vehicles, specifically truck application. The paper surveys the market currently served by diesel engines, gives an overall view of the engine application process, discusses engine-transmission-vehicle matching and performance, and details the engine services supplied by the vehicle, such as the provision of cool and clean air, water, oil, and fuel, exhaust removal, engine mounting, temperature control of the engine, coolant flow arrangements, accessories, and cold weather operation. Noise and exhaust emissions are also discussed.

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750129. Feasibility of Cooling Diesel Engines by Introducing Water into the Combustion Chamber. S. J. Lestz and R. B. Melton, Jr., U.S. Army Fuels and Lubricants Research Laboratory; and E. J. Rambie, U.S. Army Tank Automotive Command.

The feasibility of total cooling a single-cylinder diesel engine by various methods of introducing water into the

combustion chamber was investigated, including direct injection, manifold injection, and manifold induction. The effects on diesel cycle performance, fuel economy, combustion characteristics, cycle events, exhaust gas emissions, and engine wear were determined. An investigation of practical means was conducted providing for the total internal cooling of the engine to eliminate the need for jacket cooling. Design cooling parameters were determined to make the engine completely self-sustaining by providing for 100% recovery of internally injected cooling water.

1. Results show total cooling of diesel engines by direct water injection can be accomplished with increased power and better BSFC. Optimum total engine cooling by direct water injection was accomplished over a wide range of water injection timings (from 450–720 CA deg after TDC power stroke) at water/fuel ratios of 2.9–3.7 with output power and brake specific fuel consumption improved to 5–20%, respectively, over that with the standard jacket-cooled CLR engine.

2. The exhaust must be cooled to nearly 100° F at atmospheric pressure for 100% recovery of internally injected water used for cooling. Total engine cooling by direct water injection is considered impractical for engines that must operate using fans and air-to-water radiators for cooling. Potential uses of direct water injection are marine and stationary engines and for spurt power applications.

3. Emissions are affected in an expected manner by the presence of injected water: NO_x is decreased, while HC and CO emissions tend to increase. When cooling the exhaust during water recovery tests, the condensate functions as a scrubber for some emissions. Sulfur oxides are effectively scrubbed while NO_x, hydrocarbons, and CO are not removed from the exhaust.

4. Water injection contamination of the lubrication oil varies from negligible to extreme, depending on injection quantity, timing, and spray pattern. By aiming injected water at the piston head and not at the liner wall, and by keeping the oil above 212° F, the engine oil can be maintained in a dry condition.

5. No severely stressed or damaged parts of the engine cylinder, piston, valves, or rings were observed due to water injection operation. Difficulty was experienced in corrosive damage to bearings, cam, and cam follower of the water injection pump caused by water leakage into the lower end of the pump.

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750130. Draw Bead Design for Deep Profiles. Reinhardt Conrad, Reynolds Metal Co.

The design for draw beads used for deep-profiles is discussed in the paper. Draw beads are used to produce deep-drawn parts in alloy 2036-T4 and help control metal flow. They serve to prevent wrinkles and buckles in the side walls of a deep-drawn shape without having to resort to excessively high hold-down pressure which restricts metal flow. This can lead to fracture or undesirable side wall curl.

750131. Cooling Higher Horsepower Highway Diesel Engines. J. C. Walter and J. E. Hill, Cummins Engine Co., Inc.

The increase in power-to-weight ratio that results from the use of higher-horsepower diesel engines in highway service prompted this study of engine cooling. This paper covers the results obtained in testing different power-to-weight ratios on grades from sea level to over 11,000 ft and compares these results with those obtained from chassis and towing dynamometer cooling trials.

750133. (SP-392) **Quantification of Inputs for Vehicle System Analysis.** A. A. Butkunas and S. L. Bussa, Ford Motor Co.

General methods are discussed for organization and quantification of input conditions for vehicle system analysis. The input considerations are discussed for vehicle ride comfort prediction and vehicle component fatigue life estimation problems. The paper presents an overview of current work in the areas of quantification of road surface inputs to vehicles and the representation of vehicle maneuver environments for use in vehicle system analysis.

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750134. (SP-392) **Suspension System Modeling and Structural Loading.** Robert L. Davis, Chrysler Corp.

The object of this paper is to present an overview of the procedure leading to the selection of suspension system pivot points, show how to resolve terrain and maneuver loads at the tire contact patch to the vehicles' structure, illustrate the modeling technique used for stress analysis of suspension system components, and illustrate a few examples of suspension system models used to aid in the solution of ride and handling problems.

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750135. (SP-392) **Structural and System Models.** Jack K. Horvath, Cadillac Motor Car Div., General Motors Corp.

This paper illustrates the use of the System Modeling Technique as it applies to structural vibration in the vehicle shake frequency range (5-25 Hz). The emphasis is on the applicability of the approach to a variety of structural subsystem analysis and synthesis techniques. Finite element and test modeling procedures are presented in an introductory manner with references provided to furnish the theoretical aspects. Comparisons of each modeling method are discussed from the vantage point of using the simplest approach to obtain the required results. Illustrations of complete system models are given with results compared to test.

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750136. (SP-392) **Preliminary Vehicle Structural Design For Comparison With Quantitative Criteria.** Knut S. Skattum, John F. Harris and Larry J.

Howell, General Motors Corp.
To demonstrate that quantitative design criteria combined with computer analysis methods can facilitate the structural design of an automotive vehicle, two examples of computer aided preliminary design are given. The examples demonstrate analytical techniques applied at two different stages in the design process for a compact size (non-production) automobile. In the first example, analysis is applied to ensure that the front-end structure of the project vehicle is designed to withstand anticipated in-service loads. In the second example, structural dynamic analysis of the total vehicle system is performed to determine vibration response quantities in the passenger compartment. These quantities are compared with whole-body vibration criteria to assess passenger ride quality.
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750137. The Design and Testing of a Completely Waterproof Electrical Connector for Automotive Use. Ronald F. Froats, Ford Motor Co.
The need for completely waterproof electrical connectors in automobiles has been caused by the use of electronic circuitry requiring high insulation resistance between these circuits. To accomplish the necessary waterproofing together with the desirable objectives in any connector design required a new design approach and extensive testing. The various stages in developing one completely waterproof connector design are described.

750138. Sure-Seal Environmental Connectors for Automotive Electronics. David S. Goodman and Edgar Burns, ITT Cannon Electric.
A new series of environmentally-sealed connectors has been developed for automotive use. They are presently being used on truck anti-skid brake control systems. These connectors prevent the entry of moisture and dirt, and are, at the same time, resistant to hydrocarbon fluids used in and around motor vehicles—such as gasoline, motor oil, transmission fluid, etc. The operating temperature is from -40° C-+105° C. Stamped tin-plated contacts are supplied on reels for semi-automatic termination.

Two, three, and four pin connectors are presently available. Sealing boots for jacketed cable can be supplied. Special purpose Sure-Seal™ connectors are also being made to fulfill specific requirements.

750139. Effect of Wax, Plasticizer, and High Humidity on Adhesion of Polyurethane Bonded Chloroprene to Primed Steel. M. Douglas Anderson, Picatinny Arsenal.
Evaluation was made of the effects of plasticizer, wax, and high humidity on the peel strength of vulcanized chloroprene rubber bonded to primed steel with a polyurethane adhesive. Antiozone wax in rubber has a pronounced effect in reducing adhesion of the rubber to the adhesive. Dioctyl sebacate plasticizer in the rubber reduces bond strengths moderately. High humidity has a substantial deleterious effect upon the polyurethane adhesive and primer system used in this study.

750140. Anaerobic Adhesives for Sheet Metal Assembly. Charles L. Karnolt, Loctite Corp.
Anaerobic structural adhesives have been developed for use in many fields. Information is given regarding one anaerobic structural adhesive which is designed to be used in a production environment for aluminum and steel sheet fabrication. The product was tested particularly for its durability, and tests were performed mostly on production-type surfaces. These tests included heat aging, humidity resistance, weatherometer testing, and fatigue testing; repair considerations are also discussed.

750143. Rev-74—The University of Cincinnati ATV with Independent Suspension. Ivan E. Morse and William R. Shapton, University of Cincinnati.
The history and structure of the Recreational Ecological Vehicle Design Competition, REV-74, is discussed. In this competition, held at Houghton, Mich., several universities designed and constructed all-terrain vehicles which were evaluated in a series of test events. The University of Cincinnati's six-wheeled all-terrain vehicle is described in detail. Features included in the discussion are the vehicle's twin hydrostatic drive transmission, independent suspension, high-frequency muffler, and jet pump drive for water propulsion.

750144. The Design of a 4 Wheel Steer-4 Wheel Hydrostatic Drive All-Terrain Vehicle for REV-74. Fredric L. Kinney, Joseph C. Harp and John H. Johnson, Michigan Technological University.
Recreational Ecological Vehicle (REV)-74 was an intercollegiate All Terrain Vehicle (ATV) design competition organized by the Milwaukee and Cincinnati Sections of SAE. Students from six colleges built ATV's to compete May 30–June 1, 1974 at Michigan Technological University's Keweenaw Research Center test course. Competing categories of noise level, destructiveness to terrain and a 25 mile race over land and water are discussed from the viewpoint of the technical rules and as to the actual course involved with the competition.

Michigan Tech designed and built a 4 wheel steer-4 wheel hydrostatic drive ATV for REV-74. This paper provides a detailed design description of the Michigan Tech vehicle along with a review of several production ATV designs and their specifications. Finally, a report of the results of REV-74 is presented.

750145. Arizona State University's Design Approach to the REV-74 Competition. Michael J. Nielsen, Arizona State University.
The Milwaukee and Cincinnati Sections of the Society of Automotive Engineers are commended for creating the Recreational Ecological Vehicle competitions. The Society should become more involved with relevant student projects by encouraging its membership to establish and support similar events. The Industrial Design Dept. at Arizona State Univ. considers projects of this type sufficiently important to adopt them as the basis for a two semester classroom Design Project. For REV-74, this

resulted in the design and construction of an ATV that had a six wheel hydrostatic drive, independent suspension, fore and aft combined steering, and a water propulsion system.

750146. Hydrostatic Drive All Terrain Vehicle. Keith H. Hawks, School of Mech. Engrg., Purdue University.

The description of a hydrostatic transmission system designed and built for a six wheel all-terrain vehicle is given. The transmission layout and components are described in detail. The drive train basically consists of a gasoline engine, two pumps, and six hydraulic motors, one for each wheel. The theoretical total horsepower required to get the maximum pressure, 3000 psi (20.7 MPa), and flow, 15 gpm (0.057 m^3/min), capabilities of the two hydraulic systems comprising the transmission is 52.5 hp (39.1 kW).

A description of the design and construction of the vehicle with the hydrostatic drive is also given. The vehicle will accommodate one passenger, weighs 725 lb (329 kg) empty and can achieve a top speed of almost 30 mph (48 km/h). The instrument panel includes gauges for monitoring the hydraulic line pressures, flowrates and oil temperatures under actual operating conditions. The results of an extensive testing program are given.

750147. Nickel-Zinc Storage Batteries as Energy Sources for Electric Vehicles. G. Kucera, H. G. Plust and C. Schneider, Deutsche Automobilgesellschaft Forschungslaboratorium (Germany).

The first part of this paper describes factors influencing the transport output of battery driven delivery vans of the 2, 7t class. Taking into account the energy densities of batteries, the probability of their practical realization, their development costs and thermal problems as well as the payload and the necessary range of delivery vans in urban applications, a battery with an energy density of 40-60 Wh/kg can serve as energy source for a practical electric vehicle.

The second part gives details of a new developed Ni/Zn-battery which has an energy density of 45 Wh/kg and therefore corresponds to the mentioned demand.

750148. Characteristics of the Carb Tek® Molten Salt Battery. James C. Schaefer, ESB Technology Center.

A pilot line facility is in operation to evaluate the engineering and economic aspects of the Carb Tek® molten salt cells and batteries. Presently, cells are meeting the design objective of 5 Wh/in^3 (0.3 Wh/cc) of cathode, corresponding to about 28 Wh/lb (61.9 Wh/kg of cell. These cells and batteries are being designed for fork-lift truck applications. Design parameters for a 25 kW • h battery are: 720 A • h at a 6 h rate, producing in excess of 3000 Wh/ft^3 (106,000 Wh/m^3) at voltages of 30–36 V, and an energy density of about 30 Wh/lb (66.3 Wh/kg).

750149. An Overview of the Sodium-Sulfur Battery. Steven A. Weiner, Ford Motor Co.

This paper reviews the current status of work on the sodium-sulfur battery with emphasis on the ceramic electrolyte and container and electrode materials for the sulfur electrode. In addition, test results are compared with results from cells which were identically constructed except that they were metal-free. Whereas problems still remain, it is concluded that no fundamental obstacle is known which would preclude the commercial development of the sodium-sulfur battery.

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750150. Advanced Method for Reduction in Axle Gear Noise. Eiichi Abe and Hiroshi Hagiwara, Nissan Motor Co., Ltd. (Japan).

It has been successfully demonstrated that axle gear noise is greatly reduced with the addition of a simple and inexpensive device which can be mounted on either of the two side flanges of the final drive without special modifications.

The addition of this device, with the resulting additional inertia mass, makes the driveline and its vibration nonsymmetrical with respect to the final drive. This has the effect of decreasing the vibration level of the hypoid gear itself, as well as changing the resonance frequency of the driveline.

A theoretical proof is also given in which the approach is to treat the noise not as associated with the final drive itself, but as a vibration problem in the driveline.

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750151. Effect of Mounting Displacements on Bevel and Hypoid Gear Tooth Strength. Wells Coleman, Gleason Works.

An accurate appraisal of gear tooth stresses is dependent upon knowledge of the deflection characteristics of the gear mounting as well as the details of gear geometry. For optimum load-carrying capacity it is most desirable to achieve as nearly uniform load and stress distribution as possible; and thus gear mountings should be designed to this end. The equations for effective face width and load distribution factor can be introduced into the basic gear tooth strength formulas to give more accurate stress values; in this paper bevel and hypoid gears are discussed in this context.

750152. Analysis of Mounting Deflections on Bevel and Hypoid Gears. Wells Coleman, Gleason Works.

In order for bevel and hypoid gears to function efficiently, it has been established that the two mating members must be maintained in close alignment under all operating conditions. Deflection tests were made on gear mountings to determine what happens to the relative positions of mating gear and pinion and what corrective measures are required in the gear mounting to bring the relative positions within acceptable limits (those relative dis-

placements which will not severely impair the load-carrying capacity of the gears or result in noisy gears).

750154. Weight Reduction of Automotive Parts by Use of Polypropylene. Robert H. Heinold, Hercules, Inc.

Specific automotive parts in which polypropylene has been successfully used to reduce weight are presented to illustrate how the proper selection of polypropylene based materials was made and the parts were designed to meet a range of typical automotive structural requirements.

Based on these successful use histories, projections are made for future polypropylene applications which offer additional potential weight saving opportunities.

Simplified screening techniques used for quickly identifying possible weight savings and the use of sophisticated computerized design techniques for finalizing new polypropylene part designs with high confidence levels are discussed and illustrated.

750155. Weight Saving Approaches Through the Use of Fiber Glass-Reinforced Plastic. Eldon D. Trueman, Transportation Materials Div., Owens-Corning Fiberglas Corp.

Problems affecting the availability and cost of fuel have caused automotive engineers to accelerate programs aimed at making ground transportation more energy efficient. Reducing vehicle weight is considered one of the most fundamental ways to achieve that goal. Fiber glass-reinforced plastic materials offer a lightweight alternative for components which are or were manufactured from steel. Other characteristics of fiber glass/plastic make it a complete materials system with cost/performance advantages beyond its high strength-to-weight ratio.

750157. Thermoplastics Produce Significant Weight Reduction in Automotive Applications. William J. Windscheif, General Electric Plastics.

In the automotive industry today, weight reduction on the automobile has become a critical design priority. The purpose of this paper is to describe the significance of weight reduction on the automobile, to show the properties and economies of several thermoplastic resins, and to report the fit that these properties of the engineering thermoplastics have for the current design priorities calling for weight reduction on the automobile.

750158. Investigations Concerning the Employment Possibilities of the Diesel-Gas Process for Reducing Exhaust Emissions, Especially Soot (Particulate Matters). Herbert Tesarek, Institut für Verbrennungskraftmaschinen (West Germany).

In an attempt to abate soot emissions, diesel fuel for a direct-injection, single-cylinder diesel engine was step-by-step replaced with natural gas. The gas was introduced into the intake system.

As a result of this, soot emissions were decidedly improved and maximum power was increased. As an undesirable secondary effect, especially at small loads, there was an unacceptable increase in brake specific gas-diesel fuel consumption and an increase in emission of harmful gaseous exhaust components.

Exhaust gas recirculation and throttling were investigated as possible countermeasures. Both are capable of reducing the emission of poisonous gaseous exhaust components at high gas rates, without essentially increasing soot emission. Also, higher part-load consumption could be reduced by these countermeasures.

750159. An Unthrottled Gaseous Fuel Conversion of a 2-Stroke Diesel Engine. Thomas E. Ritter and Charles D. Wood, Southwest Research Institute.

The feasibility of converting a conventional unthrottled 2-stroke diesel engine to gaseous fuel was investigated. The development work was performed in two phases. In phase 1 the conversion concepts were built and tested on a single-cylinder engine. In phase 2 one of these was put into effect in a 6-cyl (DDA 6V-71) engine. The design concept with the most promise includes a divided combustion chamber utilizing a gas inlet valve in each chamber and a spark plug ignition source located in the prechamber. The concept has the potential of reducing the exhaust emissions well below the levels now existing in commercial diesels without exhaust smoke and odor and with equivalent fuel consumption and horsepower, as demonstrated in the single-cylinder conversion. Further development work remains to be done to perfect the concept for the multi-cylinder engine.

750160. Estimation of Contributed Noise Levels of Diesel Engine Components from Vibration Measurements. Andrew F. Seybert, School of Mech. Engrg., Purdue University.

An experimental technique to estimate the contributed noise levels of diesel engine components is presented. The technique predicts the contributed noise level in a reverberant acoustic environment from vibration measurements made on the surfaces of the engine components and the use of simple acoustic radiation theory. An experimentally determined value of the radiation efficiency is used in calculating the contributed noise levels. Experimental results are presented for a high speed Vee form engine. Also discussed are other techniques used to assess contributed noise levels of diesel engine components.

Discussion: S. E. Timour, Cummins Engine Co., Inc.

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750162. Design of Electronics for the Automotive Environment. L. Phoenix, Lucas Electrical Co., Ltd. (United Kingdom).

This paper takes a wide view of what constitutes the automotive environment as seen by the electronic engineer. It discusses how the design of automobile electronic equipment is affected by the cost attitude of the auto-

motive industry, the servicing facilities available, the automobile environmental conditions, and the specification of these conditions by the automotive engineer.

750163. Effects of Under-the-Hood Temperatures on Electronic Ignition Systems. Zbynek A. Capurka, Motorola, Inc.

This paper describes the influence of the wide range of temperatures on passive and active devices in the ignition system and the resulting timing variations. Electrical parameters are emphasized, and the cumulative effect on component tolerances due to different temperature phenomena is presented. The author concludes it is possible to calculate electrical performance as a function of temperature and thus design the system according to these requirements.

750165. Limits of Ride Quality Through Cab Isolation. Rush E. Allen, Lord Kinematics, div., Lord Corp.

A technique for evaluating ride quality as a function of cab isolation parameters is presented. The technique is applied to a cab-over-engine tractor to demonstrate limits of ride quality improvements.

750166. Human Vibration Tolerance Criteria and Applications to Ride Evaluation. R. N. Janeway, Janeway Engineering Co.

This paper reviews the development of criteria for human vibration tolerance, leading up to the proposed ANSI Standard (S3. 18-197x), based on the ISO Document (ISO/TC 108). This proposal is analyzed to show why its adoption is opposed in its present form, and what specific changes are recommended in keeping with the data considered most reliable. Here, special emphasis is placed on the "absorbed power" concept developed by Pradko and Lee.

Practical applications of the recommended criteria to ride evaluation are explored with specific reference to the type of measurements made. The preferred instrumentation becomes a logical outgrowth of the evaluation process.

750167. The GT-225—An Engine for Passenger-Car Gas-Turbine Research. John S. Collman, Charles A. Amann and Charles C. Matthews, Res. Labs., General Motors Corp., Richard J. Stettler, Engrg. Staff, General Motors Corp.; and Francis J. Verkamp, Detroit Diesel Allison Div., General Motors Corp.

The intensive search for an alternative low-emission powerplant for passenger cars has led to a re-evaluation of the gas turbine for this type of service. The GT-225 engine was designed as a research tool to aid in making such an evaluation. Factors which received special consideration in making design decisions included exhaust emissions, fuel economy and drivability. An extensive combustor development effort was undertaken to achieve low emissions. The engine has been installed in a test-bed vehicle to permit evaluation of emissions and other factors under actual driving conditions.

Vehicle tests of the engine fitted with a low-emission combustor demonstrated the following emissions: 0.11 g/km (0.18 g/mile) HC; 1.2 g/km (2.0 g/mile) CO; and 0.23 g/km (0.38 g/mile) NO_x. In addition, fuel economy competitive with that of conventional passenger cars at turnpike speeds, substantially improved throttle response in comparison with earlier heavy-duty turbine engines and engine braking equal to that provided by the typical powertrain in today's cars were demonstrated. Continued effort is being directed toward improvements in components, controls and engine design in order to further the potential of the gas turbine as an alternative engine for passenger cars.

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750169. Hot Corrosion Evaluation of Coated Turbine Materials. D. D. Profant and L. J. Fiedler, Lycoming Div., Avco Corp.

An environmental burner rig test has been developed to support the development and evaluation of oxidation and sulfidation resistant alloys and coating systems. This test facility has been extensively utilized in the development of inherently sulfidation resistant alloys and the evaluation of various alloy/coating systems. Environment burner rig tests have shown that the simple aluminide coatings on C101 provide exceptional resistance to sulfidation attack. These alloy/coating systems are, in fact, competitive with some of the more expensive overlay coating systems.

750170. Tests of Laser Metal Removal for Future Flexible Rotor Balancing in Engines. J. M. Tessarzik, Mechanical Technology Incorporated; and D. P. Fleming, Lewis Research Center, NASA.

This paper describes recent developments in the flexible rotor balancing technology area, with particular emphasis on methods for the addition and removal of correction weights. The currently existing Multiplane-Multispeed Balancing procedure permits one-step balancing of final shaft-bearing assemblies simultaneously in a number of planes and at a number of speeds. Temporary addition of trial weights to the rotor, and the addition or subtraction of permanent corrections, are presently performed manually in the balancing process. The addition of a computer-controlled laser device to the balancing system shows promise of eliminating direct operator contact with the rotor in the balancing process, and thus could provide a considerable increase in the precision level at a critical step in the procedure. Preliminary investigations show that design-incorporated provision of suitably-located balancing planes on the rotor, and access to those planes from outside the machine casing through portholes, should permit balancing of machine rotors in place. Check-balancing of rotors without the need for stopping the rotor appears feasible.

750171. Effects of Cell Geometry on Thermal Shock Resistance of Catalytic Monoliths. S. T. Gulati, Corning Glass Works.

The effects of cell geometry and dimensions on the thermal shock resistance of catalytic monoliths is examined analytically. Two cell geometries, namely square and equilateral triangle, are considered. Thermal gradients predicted by theory compare well with the experimental results. It is found that for equivalent thermal shock resistance the triangular cell requires lower coefficient of thermal expansion than the square cell. Also, as the cell density is increased for higher geometric surface area, both geometries require a reduction in thermal expansion coefficient to preserve their thermal shock resistance.

The above comparison does not take into account some of the other considerations which affect the overall performance, such as manufacturing advantage and the conversion efficiency. Also, the triangular cell examined has a cell density of 236/in^2 with 20% greater geometric surface area than the square cell with a cell density of 200/in^2. If the dimensions of the square cell were adjusted so as to provide the same geometric surface area as the triangular cell, it would also require lower expansion coefficient although not as low as that required by the triangular cell.

The laboratory thermal shock test to which the monoliths were subjected proved to be more severe than indicated by the threshold temperature measured by a thermocouple in the hot gas stream. Data from automobile manufacturers indicate that the honeycomb monoliths have more than adequate thermal shock resistance due to their satisfactory expansion characteristics.

750172. Pulsair—a Method for Exhaust System Induction of Secondary Air for Emission Control. Richard A. Gast, Res. Labs., General Motors Corp.

The Pulsair concept utilizes inherent exhaust system pressure pulsations to induce secondary air into reciprocating engine exhaust ports for oxidation of unburned hydrocarbons and carbon monoxide. High-speed check valves are actuated by subambient exhaust pressures which arise from reflected exhaust "blowdown" pressure waves. For multicylinder engines, a single check valve set can be used effectively to supply air to an entire exhaust manifold.

Experiments with V-8 engines and simple acoustic wave theory have been used to define system fundamentals and design techniques for obtaining high induced airflow rates at specified engine speeds. Procedures are outlined for adapting the concept to L-4, L-6, and V-6 engines.

The Pulsair system does not affect net engine power and is potentially less complex than typical air pump systems. Sufficient air can be induced to meet the expected secondary air requirements for many exhaust aftertreatment systems; however, some modifications to conventional exhaust systems may be necessary. For example, Pulsair rates as high as 60% of engine airflow have been demonstrated by modifying the exhaust crossover of a V-8 engine.

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750173. Exhaust-Port Fuel Injection for Chemical Reduction of Nitric Oxide. Donald J. Pozniak, Res. Labs., General Motors Corp.

Nitric oxide can be chemically reduced in a vehicle exhaust system if hydrocarbons are supplied to high-temperature exhaust gas near the engine exhaust valves. Ethane was injected into the exhaust ports of engines equipped with either stainless steel or ceramic thermal reactors. Thermal decomposition of the ethane provided hydrogen and hydrocarbon radicals for the gas phase chemical reduction of nitric oxide formed in the engines.

Although significant reductions of nitric oxide were achieved, severe spark retard was required to attain the elevated exhaust temperatures required to effect the nitric oxide reduction. Furthermore, carbon monoxide, hydrogen cyanide, and ammonia were formed, especially with the stainless-steel reactors. In view of these findings, this scheme for reducing nitric oxide emissions is not felt to be practicable for automotive application at this time.

750174. The Importance of Secondary Air Mixing in Exhaust Thermal Reactor Systems. Ronald J. Herrin, Research Labs., General Motors Corp.

Automotive thermal reactors have obtained high conversion efficiencies on engines with very rich carburetion, but fuel economy and reactor durability have suffered. Improved mixing of exhaust gas and secondary air in the engine exhaust port was examined as a means of improving reactor efficiency at less rich engine air-fuel ratios. Three air-injection systems which span a broad range of mixing capabilities were examined. Mixing characteristics were deduced from anemometry measurements of instantaneous secondary airflow, and emission performance of each system was generalized by a test program employing four steady-state conditions.

High-pressure, timed air injection provides the best mixing and the best reactor performance. Sparger (radial discharge) air injection tubes provide fair mixing and better performance than conventional open-ended air injection tubes, which exhibit poor mixing characteristics. Performance with sparger tubes is significantly poorer than with timed injection, but sparger tubes are more practical in terms of cost, complexity, and durability.

750175. Gas Phase Effects in a Monolith Converter Model. David S. Dickey, Res. Labs, General Motors Corp.

A steady-state, mass-transfer-limited monolith model has been formulated to investigate analytically the effects of gas-phase phenomena on converter performance. Gas-phase reaction kinetics are included to demonstrate the significance of noncatalytic processes to overall conversion, especially at temperatures above 850K. Developing

boundary layers in the monolith channels are shown to increase the calculated conversions relative to conditions for fully developed, laminar flow. Substantially different conversion efficiencies are predicted for various hydrocarbon species because of the effect of component diffusivity on convective mass-transfer rates.

The expression for the gas-phase oxidation of hydrocarbons indicates that carbon monoxide forms as an intermediate product. Experimental evidence of carbon monoxide formation in conjunction with high concentrations of inlet hydrocarbons has been modeled with this partial oxidation reaction. Comparisons of the model calculations with other experimental results reveal important trends which are related to the gas-phase reactions. Over-prediction of the magnitude of the hydrocarbon conversion occurs because the mass-transfer-limited assumption is probably inapplicable to some hydrocarbon species.

In addition to quantifying the effects of gas-phase phenomena, areas for additional research have been identified: improvement of expression for gas-phase kinetics, measurement of hydrocarbon species distributions, and quantification of kinetic limitations for catalytic conversion in monoliths.

750176. Dual Catalytic Converters. S. L. Genslak and J. A. Zahorchak, Engineering Staff, General Motors Corporation.

The stringent 1978 emission standards of 0.41 gm/mi HC, 3.4 gm/mile CO, and 0.4 gm/mi NOx may require the use of a dual catalytic converter system (reducing and oxidizing catalyst). These emission requirements have been achieved at low mileage with such a system, but it is complex and has exhibited poor durability. This system also results in the loss of fuel economy at the 1978 emission levels.

750177. Durability Testing of Stabilized Ru-Containing Catalysts. H. S. Gandhi, H. K. Stepien and M. Shelef, Scientific Res. Staff, Ford Motor Co.

Ruthenium-containing catalysts have good activity and selectivity for the reduction of the nitric oxides in automobile exhaust. Although designed to be operated under reducing conditions, these catalysts lose Ru by volatilization when subjected to lean transients. Attempts were made to stabilize these catalysts against volatilization by forming stable ruthenates. This paper deals with durability testing of stabilized ruthenate catalysts on a laboratory bench set-up, dynamometers, and vehicles. Post-mortem analysis of the durability-tested catalysts are presented showing the extent of stabilization. The results show that the Ru loss from ruthenate catalysts in present vehicle systems is in excess of acceptable limits. These losses can be minimized further, but at a cost of reduced selectivity in the NO reduction. Substantial further improvements are needed to achieve the required performance characteristics.

Another problem is the poisoning by S, Pb and P. The catalysts have been analyzed to determine the various poisons deposited by the engine exhaust. The retention of Pb, S, and P by catalysts from exhaust was determined in well-controlled dynamometer tests. The BET area and active metal area were measured before and after the tests to determine the extent of thermal sintering. Actual temperature traces of catalysts under customer-type driving have shown temperature excursions up to 1900°F.

750178. Reliability Analysis of Catalytic Converter as an Automotive Emission Control System. K. Matsumoto, T. Matsumoto and Y. Goto, Toyota Motor Co., Ltd.

A reliability analysis was conducted by means of the failure mode effect analysis technique on the catalytic converter which has been adopted in the 1975 Toyota models. A series of vehicle tests was conducted to determine the failure modes criticality. The study was performed on a precious metal pelleted catalyst. Critical durability failure modes to the durability of the catalytic converter and their criticality were classified and substantiated through this study. The results are presented and discussed.

The results obtained by this analysis are useful for improving the reliability of the catalytic converter.

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750179. Catalytic Emission Control System Field Test Program. Donald L. Miles, Engineering Staff; Louis J. Faix, Chevrolet Engineering; Harry H. Lyon, Oldsmobile Division; and George W. Niepoth, Engineering Staff General Motors Corporation.

A fleet of nearly 250 cars equipped with experimental catalytic converter systems were tested in taxi, police, state, and municipal fleets in various cities throughout the country. This provided a diversified range of customer service and altitude and climatic conditions. The objective was to evaluate the performance and durability in high mileage field service of experimental catalytic emission control systems. The fleet comprised groups of cars with hardware and calibration variations designed toward the 1975 Federal and California and more advanced emission requirements. The converter systems evaluated were primarily a 260 cubic inch underfloor converter and a 140 cubic inch manifold converter. Both bead and monolith substrate catalysts were examined.

Test results showed that on the average the systems successfully controlled emissions to below the 1975 Federal and California requirements for greater than 50,000 miles. Engine misfire conditions did cause converter damage in some instances. Systems designed for the low emission requirements of .41/3.4/.40 grams/mile HC/CO/NOx exceeded those levels at relatively low mileage due to catalyst deterioration.

750180. The Outlook for Aluminum in Automobiles. Jame A. McGowan, Aluminum Company of America.

This paper is an overview of the future aluminum metal supply situation, the aluminum industry's energy requirements and the potential for recycling aluminum from scrap autos. Within this framework, pricing, energy conservation and the industry's technological progress in the automotive field are also discussed.

750181. Copper—An Available Resource for the Future. W. Stuart Lyman, Copper Development Association, Inc.

The U.S. copper and brass industry has just demonstrated in a record-breaking production year (1973) its ability to supply mill products to meet customer needs in a period of high cyclical demand. The industry, in cooperation with its customers, is engineering ever more usefulness and value into each pound of copper used. New applications based on copper's unique combination of properties and on the changing needs of society are in the prototype stage of development. And at a time of upheaval in world markets, the U.S. can depend on its own self-sufficiency in copper—the earth's most recyclable resource.

750183. Inorganic Chemicals Technical Service and Development. C. W. Nelson, Dow Chemical Corp., U.S.A.

Magnesium, like so many other metals, is experiencing a period of short supply. While, as of this writing, fourth quarter of 1974, there is some softening of the market for metals such as aluminum and zinc, magnesium continues to be short. The short supply of magnesium will unfortunately restrict its use in two potential growth markets —steel desulfurization and die casting. However, the desire of the automotive companies to reduce the weight of their cars and the projected energy requirements to produce magnesium makes the future look good for this metal.

The use of magnesium in the die casting market will eventually grow as the energy requirements to produce magnesium become competitive with aluminum on a unit volume basis. Magnesium's raw material source of supply, sea water, is constant; and the process of electrolytic extraction will be continually improved from an energy and cost standpoint. Bauxite quality is gradually deteriorating and will eventually drive aluminum production energy requirements up. The fact that most bauxite sources are outside of the United States is also in favor of magnesium.

750184. Zinc, a Versatile, Strategic World Commodity —Its Position in a Changing Market. M. Robert Davidson, Noranda Sales Corporation.

A presentation on zinc demonstrating its versatile applications to the auto industry. A review of metal balances, domestic, world and major producing countries. The energy required to mine, smelt and refine zinc is compared to other metals. The value of recycling zinc is also considered. This paper concludes with a statement, supported with evidence, that today's automobile is a better buy than twenty years ago.

750187. Raw Material Sources for Automotive Plastics. Zack G. Garlund, Research Labs., General Motors Corp.

The sources of raw materials available for production of the major automotive plastics have been determined. In order to do this, each polymer was broken down into its monomeric units, and the basic chemicals used in the commercial synthesis of each monomer were specified. Three alternate raw material sources are discussed. Coal is an excellent source of chemicals, especially acetylene, needed for polymer production. Oil shale retorting yields a large number of basic chemicals. Two major chemicals are also available from agricultural products and residues. Although each source has its disadvantages, there is no problem in the amount of chemicals that can be obtained.

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750188. A Sampling Program for Evaluation of the 1974 Restraint Systems. Robert E. Scott and James O'Day, Highway Safety Research Inst., University of Michigan.

In-depth accident investigation programs in the past typically have not been addressed to specific research questions, nor have they been based on the principles of experimental design. This paper describes the design and implementation of an ongoing program for measuring the performance of the 1974 restraint system in actual crashes. Sampling techniques using a stratified systematic sample are used to compare the injury experience in 1973 and 1974 passenger cars. The design and implementation of the data collection and analysis as an integrated program are discussed, and preliminary findings are presented.

750189. Seat Belt Use Laws: A Solution to Occupant Fatality and Injury Reduction. H. George Johannessen, Hamill Manufacturing Co., div. Firestone Tire and Rubber Co.; and Charles H. Pulley, American Safety Belt Council.

Recent surveys and investigations provide significant additional evidence that seat belts when worn can provide the greatest vehicle occupant protection of all currently available occupant restraint systems. Seat belts are effective and cost-effective, and are universally installed. Acceptable levels of seat belt usage can be attained through appropriate regulatory action requiring improvements in comfort and convenience of seat belt systems, and legislative action by the states to assure usage.

750190. 1974 Accident Experience with Air Cushion Restraint Systems. Russell A. Smith and Charles J. Kahane, Natl. Highway Traffic Safety Admin., U.S. Dept. of Transportation.

An air cushion restraint system has been available to the public on certain model passenger cars since January 1974. In response to this opportunity to obtain field experience, the National Highway Traffic Safety Admin-

istration has established a nationwide reporting network and investigative capability for accidents involving air-bag equipped cars. The reporting criteria for accidents require that the car be towed as a result of the accident, or that a front-seat occupant was injured, or that bag deployment occurred. The principal objective is to obtain the injury-reducing effectiveness of this restraint system in the total accident environment. This environment encompasses "towaway" accidents resulting in bag deployment and non-deployment. Definitive results are expected at the conclusion of the study. This paper summarizes the experience during the first year of the program, during which time the rate of accident occurrence was far less than originally expected.

750192. Silent Rider—A Project for City Center Transport. C. Morris, Chloride Technical Ltd. (United Kingdom).

The rapidly advancing technology in areas associated with battery-powered vehicle development is greatly enhancing the opportunities for such vehicles in the marketplace. However, the inherent inflexibility of such vehicles consistent with competitive economics of operation limits their possible applications. One such application has been identified by surveys and analyses in the Greater Manchester area as city center and conurbation public service vehicles, where up to 40% of duties can adequately tolerate the limited range of battery-powered vehicles within their method of operation.

In order to evaluate the energy conversion efficiencies of a full size battery-powered bus, the Chloride Group in conjunction with the Greater Manchester Passenger Transport Executive has developed a prototype 50 passenger, 40 mph battery-powered vehicle named Silent Rider. During test programs on the prototype it has been found that the overall efficiency of the vehicle can be increased from 60% to 72% by the addition of regenerative braking facilities. Several areas requiring further development have been clearly defined resulting from preliminary testing of Silent Rider.

750193. Electrical Propulsion Systems for Battery Driven Road Vehicles with Hydrodynamic Transmission of Power. C. Bader, Deutsche Automobilgesellschaft Forschungslaboratorium (Germany).

In view of the low energy density of the electrochemical storage units available at the present time, only the development of such electric vehicles that are intended for transportation jobs within the cities appears to be worthwhile. The speeds mainly used with this type of application can be controlled by field weakening of the electric motor. The function of the power electronics which serves only to control the starting range can be taken over by a hydrodynamic transmission. In this case, the design of the drive must take into consideration the basic differences between the torque versus speed characteristics of a hydrodynamic converter and an electric motor. With a suitable design, this power train has, on the one hand, a good efficiency of transmission and can meet, on the other hand, further demands conditioned by the energy storage.

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750194. A Method for Estimating Mileage Improvement and Emission Reductions Achievable by Hybrid-Electric Vehicles. Thomas A. Nondahl and Donald W. Novotny, University of Wisconsin.

The results of two derivations relating to the fuel economy of hybrid-electric vehicles (vehicles which employ both a heat engine and electric drive system) are presented and their use is illustrated through the examples of the University of Wisconsin and TRW Systems Group hybrid-electric vehicles.

The method of mileage estimation employs a specific fuel-consumption versus torque-speed map for the heat engine under study and knowledge of the hybrid-vehicle dynamics and road-load power. The method is easily extended to estimation of emission reductions through use of specific-emission-production versus torque-speed maps and is applicable to hybrid vehicles with other than electrical energy-storage systems.

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750195. Advances in Low Temperature Liquid Nitriding. Robert H. Shoemaker, Kolene Corp.

Low temperature liquid nitriding is performed in a carbon and nitrogen fused salt bath as a single step hardening process. The two hour heat treatment produces substantial endurance and wear properties. Future planning for small size vehicles in the automotive industry includes low temperature liquid nitriding applications. Crankshafts, rocker arms, rocker arm shafts, camshafts, differential housings and gears all benefit from this specialized heat treatment. Cost advantages may be realized by low temperature liquid nitriding of carbon steel as a substitute for alloy steels.

750196. Practical Application of Forward Extrusion Theory. Michael E. Ward, Engrg. Office, Chrysler Corp.

Using experimental methods, many forward extrusion theories have been verified. An energy analysis most accurately predicts extrusion strain, load, and material strengthening resulting from the process. The occurrence of chevrons can also be defined, and tool modifications can be specified to avoid this problem.

750197. Sheet Metal Stretch Flange Analysis: A Manufacturing Viewpoint. A. S. Kasper, W. L. Weeks and M. P. Borden, Chrysler Corp.

Sheet metal forming difficulties often stem from splits in flanges. A technique to analyze strain at flange edges is described. The effects of stress concentrators, that is, tabs and cutouts, and burrs are shown. Some edge strain limits are also presented.

750198. Effects of Graphite Morphology, Matrix Hardness, and Structure on the Fatigue Resistance of Gray Cast Iron. M. R. Mitchell, Department of Theoretical and Applied Mechanics, University of Illinois.

The fatigue resistance of gray cast iron is shown to be strongly dependent on graphite morphology and the strength of the steel-like matrix. Considering graphite flakes in gray iron as internal notches, a comparison is made of the fatigue resistance of gray irons and steels of comparable composition, hardness, and microstructure. Application of a Neuber analysis, previously employed in geometrically notched members to relate nominal stresses and strains to local stresses and strains at notch roots, produces quantitative values of the fatigue notch factor, K_f, for various graphite morphologies, matrix structures, and hardnesses. Fatigue resistance of gray irons is enhanced by decreasing graphite flake size. Matrix hardness is of greater importance than structure in determining the fatigue resistance.

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750200. (SP-393) **Electronic Equipment Earning Its Place On European Vehicles.** C. S. Rayner, Lucas Electrical Co., Ltd. (United Kingdom).

The paper traces the development of European vehicle electronics from 1960 to the present day. The approximate current rates of production of alternator regulators, tachometers, fuel injection controllers and ignition equipments are quoted. Analysis of the development of a product design of an alternator regulator is carried out and reference made to some ways of achieving high reliability in the hostile underhood environment. The impact of legislation on the emergence of electronic ignition is discussed. Some likely effects of device evolution on current design are mentioned and pointers given to the expected patterns of future developments for European vehicle electronics.

750201. (SP-393) **Electronic Equipment Usage on Japanese Vehicles.** G. P. Lemberg, International Quantum Science Corp.

The application of a wide assortment of electronic systems to motor vehicles currently under serious consideration in the automotive and electronic industries would provide a number of advantages such as improved service and maintenance, better performance and reliability, and improvements in safety as well as emission control. At present, the substantial use of electronics is limited to only a few automotive systems—alternator, auto radio, and stereo. However, signs of electronization in other auto systems such as regulators, fuel injection systems, ignition systems, lighting systems, power control systems, clock, etc. are becoming apparent and will be discussed at length in this portion of the study.

The regulatory environment for auto safety and air pollution control is one of the more influential factors for auto electronization. The domestic regulatory environment for auto safety is somewhat different from that in the United States. Currently, Japan does not have any safety regulation which necessitates the use of electronic systems, a situation arising from differences in traffic conditions between the two countries. Therefore, rapid increase in demand for electronic systems is not expected in the next few years. But it should be kept in mind that the Japanese auto industry is strongly influenced by changes occurring in United States safety regulations. To cite an example, Japanese auto makers are required to install ignition interlock systems for seat belts on autos to be manufactured and exported to the United States market after August 15 of this year. However, in the area of emission control Japan will have severe standards effective after 1975, which will require an increase in the use of electronic systems. However, when considering the future of electronization, we must take into consideration the influence of the Honda CVCC engines which require no electronic control systems to satisfy severe emission standards.

As concern over auto electronization has increased, better communication between the auto and electronic industry has been promoted and achieved through the establishment of the Committee of Auto Electronics, a special group within the Japan Society of Automobile Engineers, Inc. With this selected committee, members from both industries are able to exchange technical information concerning the application of electronics to motor vehicles, and in establishing standards for auto electronic components. In addition, joint R&D activities between individual auto and electronic component makers have also been accelerated.

Joint venture companies established by auto and electronic component manufactures for R&D and manufacture of auto electronic systems are looked upon as prime promoters of auto electronization. Nippon Denshi Kiki (Japan Electronic Systems), established by Robert Bosch of West Germany; Nissan, Isuzu, and Diesel Kiki, for manufacturing electronic fuel injection systems, Fujitsu-Ten, joint venture company by Toyota, Nippon Denso and Fujitsu, for R&D and manufacturing of various auto electronic systems, IC's, radios and stereos, are the pioneers of such joint venture companies.

Development of new techniques to apply electronic systems to a number of applications within the automotive system, such as in-transit communication, diagnostic systems, and accident prevention, will be the goals sought through the cooperation between both industries.

750202. (SP-393) **Auto Electronics: A Semiconductor Supplier's Viewpoint.** Robert M. Cohen, RCA Corp.

This paper reviews the steps taken by the semiconductor industry to be responsive to the requirements of the automotive industry, with special emphasis on one recently developed and highly cost-effective method to control and improve device reliability. Two new product innovations, one combining MOS and bipolar technology

to produce a high performance and versatile operational amplifier integrated circuit, and the other an inherently more reliable process for IC manufacture involving a hermetic silicon die and a corrosion resistant lead connection system are also described, particularly as they relate to automotive applications.

750203. CRC Evaluation of Techniques for Measuring Hydrocarbons in Diesel Exhaust—Phase IV. T. O. Wagner, American Oil Co., div., Standard Oil Co., L. C. Broering, Cummins Engine Co., Inc.; and J. H. Johnson, Michigan Technological Univ.

In 1972 and 1973, the CRC-APRAC Program Group on Diesel Exhaust carried out a fourth program to evaluate techniques for measuring concentration of hydrocarbon in diesel exhaust. The first two programs were conducted in 1967 and 1968. In them, a single cylinder diesel engine was shipped among 13 laboratories and each laboratory measured hydrocarbon emissions by their own method. Agreement among laboratories (instruments) was poor in both programs. The third program was conducted in 1970 at one laboratory on one engine. This time, agreement among instruments was much improved from the earlier programs. The fourth program was conducted to confirm these later results. In it, a multi-cylinder diesel generating set was circulated among 15 participating laboratories, and each laboratory measured exhaust hydrocarbon by methods that complied with SAE Recommended Practice J215, "Continuous Hydrocarbon Analysis of Diesel Exhaust." They also measured hydrocarbon concentrations of two bottled gases having unknown compositions. Analyses were fairly consistent within laboratories both on bottled gases and engine exhaust: the standard deviations were 3% and 10% of the grand averages, respectively. However, analyses differed substantially among laboratories both on bottled gases and engine exhaust; the standard deviations were about 10% and 22% of the grand averages, respectively. These results scatter more than desirable for engineering measurements, and they indicate that further improvement should be sought in techniques for analyzing hydrocarbons in diesel exhaust.

750204. Cooperative Evaluation of Techniques for Measuring Nitric Oxide and Carbon Monoxide (Phase IV Tests). J. M. Perez, Caterpillar Tractor Co., L. C. Broering, Cummins Engine Co., Inc.; and J. H. Johnson, Michigan Technological Univ.

This is the fourth in a series of tests conducted as a Coordinating Research Council cooperative program to evaluate the measurement methods used to analyze diesel exhaust gas constituents. A multi-cylinder engine was circulated to 15 participants who measured emissions at three engine conditions. All 15 participants measured nitric oxide and carbon monoxide with several laboratories measuring nitric oxide by both NDIR (Non-Dispersive Infrared) and CHEMI (Chemiluminescence). Some participants also measured carbon dioxide, nitrogen dioxide, oxygen, and unknown span gases. The test results are compared with the Phase III cooperative tests which involved simultaneous measurement of emissions by participants. The precision of the results was poorer in Phase IV than Phase III.

750205. Diesel Emission Control Through Retrofits. Karl J. Springer, Southwest Research Institute; and Ralph C. Stahman, U.S. Environmental Protection Agency.

Exhaust emissions from in-use diesel trucks and buses can be reduced by application of retrofits consisting of new parts and adjustments. The results of fleet test demonstrations of two retrofit kits, one for 2-stroke diesel-powered buses and the other for 4-stroke diesel trucks, are described. Except for the catalytic muffler, the components and adjustments composing the General Motors environmental improvement proposal kit for General Motors city buses were found helpful in reducing exhaust odor, smoke, and certain gaseous emissions. The turbocharger kit and adjustments marketed by Cummins Engine for its NHC 250, an in-use naturally aspirated truck engine, was likewise found to reduce visible smoke satisfactorily. The fleet test data are from three city buses operated for two years and three intercity truck tractors operated for eight months.

750206. Temperature Measurement for Advanced Gas Turbine Controls. David A. Rohy, T. E. Duffy and W. A. Compton, Solar Div., Intl. Harvester Co.

Modern gas turbine engines with turbine inlet temperatures higher than metal melting temperatures must have control systems which provide subsecond response to changes in gas or metal temperatures. High quality data are required to provide for the most efficient engine operation consistent with engine safety.

Recently developed instruments measure individual blade temperature; another non-immersion gas temperature sensor, not yet fully developed, will provide accurate gas temperature data up to 1900°C. These instruments are described with present and potential uses in control systems.

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750207. Temperature Measurement for Gas Turbine Engines. W. J. O'Brien, Detroit Diesel Allison Div., General Motors Corp.

With the expanding application of gas turbine engines for stationary and ground vehicle use, more people are exposed to the problem of protecting the engines from excessive temperatures. Most engines today use some system involving thermocouples to measure temperature for manual or automatic control.

Various sensor configurations have been developed and examples of each are available which have been selected based on the following: gas temperature to be

sensed, response requirements of the controls, environment surrounding the assembly, and annular depth available for sampling.

Most engines employ more than one thermocouple, and the signals are supplied to an engine mounted harness which provides an electrical average of the signals to the indicator or control. Most harnesses in use are electrically either a common point system or an equal resistance branch system fabricated of protection materials selected for the temperature environment in which they exist and the type of handling and abuse to which they will be subjected.

The engine manufacturer must establish the control requirements for the engine which dictates the location and number of thermocouple and the environmental conditions to which the system will be exposed.

Having determined the basic requirements of the system, the engine manufacturer can make use of the engineering skills, materials, and sources developed primarily for aerospace.

750208. Performance and Application of the Exducer Power Turbine. Colin Rodgers, Solar Div., International Harvester Co.

During the development of the Solar Titan T-62, small gas turbine engine, for the U.S. Navy, a two-shaft version was performance tested incorporating a unique turbine configuration in which the exducer portion of the radial inflow turbine was employed as a nozzleless free power turbine.

This paper reviews the development of this interesting small gas turbine and presents the performance results obtained while operating the engine over a range of compressor and power turbine speeds.

750209. Early Detection of Defects in Rolling-Element Bearings. Mark S. Darlow and Robert H. Badgley, Mechanical Technology Inc.

This paper presents the results of studies which demonstrate the feasibility of the High-Frequency Resonance Technique for defect analysis of rolling-element bearings in virtually any bearing system. Specific emphasis was placed on helicopter engine and transmission applications. The HFRT is a method for separating ball-pass or roller-pass frequency peaks from background noise by isolating and demodulating high frequency spectrums of accelerometer signals. The process is also called envelope detection.

Tests were conducted with bearings from a UH-1 helicopter transmission to show the effectiveness of the HFRT explicitly for that application and implicitly for other bearing applications. The resonance peaks for these tests were selected by inspection of raw data signals and were found to correlate reasonably well with predictable bearing race natural frequencies. The test bearings were mounted in a rotating dynamic response test rig and run under various conditions of speed, load, and bearing housing design. Both good bearings and bearings with artificially-induced discrete defects were tested. Signals were recorded from accelerometers located in various positions. The resulting data was analyzed using the HFRT, and showed as much as an order of magnitude increase in the amplitude of the envelope-detected ball-pass or roller-pass frequency peaks for the bearings with the defects as compared to the same bearings without defects. Variations in speed and load were found to have relatively little effect on the defect signals' magnitudes.

Similar signals were recorded from accelerometers mounted externally on an operating UH-1 helicopter main rotor drive transmission during ground tests. This data, analyzed using the testing criteria developed from the results of the test rig investigations, shows that the HFRT can readily detect bearing defect signal components in the presence of high background noise levels, such as those which would be encountered in a turbine engine. In combination with the test rig results, these results infer that the HFRT is not only feasible for use with the bearings of a UH-1 helicopter transmission, but may also be applied to other bearing systems as well.

750210. Torque Characteristics of Commercial Vehicle Brakes. Thomas M. Post, Paul S. Fancher and James E. Bernard, Highway Safety Research Institute, University of Michigan.

A new over-the-road brake dynamometer has recently been developed to measure commercial vehicle brake torque at nearly constant speed. In this paper, results are presented from the initial test program of this vehicle. The program included tests to assess the influence of initial drum temperature and rubbing velocity on brake torque, as well as the occurrence and nature of brake fade and hysteresis effects. Results of these tests indicated that the rate of energy flow into the brake system had a more significant effect on brake torque than initial temperature. Greater hysteresis was found in the S-Cam brakes than in the dual-wedge brakes.

750211. Determination of Tire Characteristics from Vehicle Behavior. Allan I. Krauter, Shaker Research Corp.

This work is concerned with the development of a procedure for the determination of truck tire characteristics from truck behavior measurements. The procedure investigated involves determination of these characteristics by matching the behavior of a full size tractor-semitrailer truck with that of a simulated truck. The matching is accomplished using an optimization procedure. The results obtained show that the procedure can provide satisfactory estimates of actual tire characteristics under some conditions. Limitations associated with certain aspects of the procedure are studied.

750214. New Transit Modes: Applicability and Current Status. Charles P. Elms, N. D. Lea Transportation Research Corporation.

A survey of new urban transportation systems around the

world reveals that four significant technology classes are presently emerging: Moving Way Transit (MWT), Light Guideway Transit (LGT), Personal Rapid Transit (PRT), and Dial-A-Bus (DAB).

The author concludes that LGT is state-of-the-art, that accelerating MWT systems are at an awkward state with respect to the marketplace, that high capacity PRT appears to be no less than four years away from state-of-the-art and that DAB systems are operational.

The general theme of the paper gives the status of development of the technology classes and their applicability and availability to a defined set of urban scenarios.

750216. The Effect of Automatic Transmissions on Military Truck Fuel Economy. Wayne K. Wheelock, U.S. Army Tank-Auto. Command.

The purpose of this paper is to describe investigations made of military truck fuel economy with various types of transmissions and to present resulting data and conclusions. The primary factors influencing fuel economy in the military environment are identified. Vehicles were specially prepared and operated over a military type duty cycle at various speeds and loads with professional and novice drivers.

The resulting data indicates that in a military on-off road duty cycle automatic transmissions will provide fuel economy superior to nonautomatic transmissions, particularly when novice drivers are utilized.

750217. A Cybernetically Coupled Research Vehicle. Ronald R. Beck, U.S. Army Tank-Auto. Command; and Irmin O. Kamm, Stevens Inst. of Tech.

A test vehicle has been built and tested which couples two M-113 armored personnel carriers using a cybernetically controlled articulation joint. This vehicle has demonstrated an outstanding increase in off-road mobility, especially in its step and trench crossing, and water-exiting capabilities.

750219. Three Generations of Soviet Wheeled Military Transport Vehicles. Donald R. Warner, U.S. Army.

The U.S.S.R. development and production of wheeled military transport vehicles since the end of World War II are analyzed as three generations of vehicles in this report. The 21 vehicles included in these generations are identified and characterized. Vehicular design details are described in terms of overall vehicle mobility, efficiency, and durability. Trends in component design which affect vehicle mobility, efficiency, and durability are presented. This review is the product of literature searches and is an independent assessment of Soviet developments.

750220. Evaluating the Effects of Corrosion on Structural Materials—A Study of Plain Carbon and High Strength Low Alloy Steels. William K. Miller, Res. Labs., General Motors Corp.

A variety of high strength low alloy (HSLA) steels have been corrosion tested and compared with plain carbon steel. No highly significant differences were found in their uniform corrosion rates. However, reductions in tensile load carrying ability were proportionally greater for the higher strength steels, and ductility losses increased as the initial thickness of the steel decreased. As a result, corrosion prevention can be more important for structures made from HSLA steels, particularly when use of a HSLA steel has resulted in designs with reduced material thickness.

750221. High Strength Materials and Vehicle Weight Reduction Analysis. D. G. Adams, J. A. DiCello, C. Hoppe, A. S. Kasper, A. N. Keisoglou and W. W. McVinnie, Engrg. Office, Chrysler Corp.

Advancements in high-strength-to-weight-ratio material development have provided the automotive industry with numerous possibilities for vehicle weight reduction. The application rate of these new materials will depend upon their economic feasibility as well as their material properties. For these materials to be cost effective, the weight interaction of lighter high strength components must be considered within the environment of the total vehicle. This paper presents an analytical technique for quantifying vehicle component weight interactions and specifying the resulting iterative weight reductions that can be achieved through high strength material substitution. The technique has been applied to a typical production full-size vehicle to obtain the hypothetical, component group-weight targets that could be achieved through substitution of high strength-to-weight-ratio materials. Finite element computer models were created, representing the typical production vehicle and the resulting lightweight, high strength vehicle. These theoretical models were then computer tested, statically and dynamically, to ascertain the differences between the typical production vehicle and the lightweight, high strength vehicle. The results of this theoretical structural testing are given.

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750222. Development of Lightweight Door Intrusion Beams Utilizing an Ultra High Strength Steel. T. E. Fine, Inland Steel Co.; and S. Dinda, Chrysler Corp.

Door intrusion beams have been fabricated from an ultra high strength steel resulting in an efficient side impact protection system. Despite the ultra high strength (yield strength ~150 ksi) the steel may be roll formed into beams from thin gauge material (0.035 in) resulting in significant vehicle weight savings while still meeting all federal specifications. This paper covers the development of this door intrusion beam system and includes detailed descriptions of beam design, beam testing and steel properties.

750223. Ceramic Aspects of the Bosch Lambda-Sensor. Heinrich Dueker, Karl-Hermann Friese and Wolf-Dieter Haecker, Robert Bosch GMBH (Germany).

The Λ-sensor is used within the scope of the Bosch emission control system, representing a closed control loop. In principle, it is an oxygen concentration cell with an oxygen ion-conducting solid electrolyte which provides a sharp voltage step at the stoichiometric air-fuel ratio, serving as a control signal. Zirconia ceramic stabilized with certain metal oxides is used as the solid electrolyte. The electrical and mechanical properties of the ceramic depend, above all, on the type and concentration of the stabilizing oxide and on the manufacturing conditions. Using ceramic materials which are described, sensors can be produced that make possible exact control of the stoichiometric A/F in a temperature range of 300/400-900° C. The lifetime of the sensor, which depends on the operating conditions, can be taken as about 15,000 miles of driving distance. With this sensor, exhaust emissions can be kept below the limits specified for 1977–1978 in the United States.

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750224. Automotive Exhaust Sensors Using Titania Ceramic. E. F. Gibbons, A. H. Meitzler, L. R. Foote, P. J. Zacmanidis and G. L. Beaudoin, Scientific Research Staff, Ford Motor Co.

The resistivity of titania (TiO_2) ceramic depends upon the partial pressure of oxygen (Po_2) in the atmosphere surrounding the ceramic. Because there is a functional relationship between the Po_2 of the equilibrated exhaust gas and the air to fuel ratio (A/F) operating point of the internal combustion engine, the resistance of a TiO_2 ceramic sensor, when temperature controlled, can be used to determine quantitatively the A/F. TiO_2 sensors utilizing these principles have been built and found to work particularly well in the region rich of stoichiometry. Control of the A/F in the region rich of stoichiometry is desirable for engine/catalyst systems designed to meet low NO_x emission levels.

This paper reports on the design details and operating features of an experimental TiO_2 sensor and its associated electronic controller. In addition, experimental results are reported for the sensor/controller combination operating in engine dynamometer tests and on vehicles with feedback-controlled, electronic fuel injected engines. These results indicate that feedback control using the TiO_2 sensor represents a possible means of achieving the precision A/F control required to obtain efficient performance of vehicles using NO_x catalysts.

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750225. Platinum Film Temperature Sensors. G. S. Iles, Johnson, Matthey and Co. Ltd. (United Kingdom).

A novel temperature sensor is described, consisting essentially of a composite platinum film firmly bonded to a ceramic substrate.

The film is protected from the corrosive effects of gaseous environments by an overglaze of impervious glass, forming a device that is mechanically and thermally robust. Since the sensing unit does not require further protection by encapsulation in a metal or ceramic sheath, it responds very rapidly to thermal changes.

The sensor possesses short and long term electrical characteristics similar to those of wire-wound platinum resistance thermometers, but is less costly. It can operate over a wide range of temperatures up to about 1,000° C.

The versatile construction of the sensor renders it, in its cylindrical form, eminently suitable for monitoring the thermal changes occurring within catalyst emission control units on internal combustion engines. Dependent upon associated electronic circuitry, the device can operate visual and/or audio signals and trigger electromechanical functions informing a driver of the condition of these units.

750228. The Manufacture of Disc Brake Linings. Gerald R. Russell, Delco Moraine Div., General Motors Corp.

The primary responsibility of the process is to produce linings repeatedly that meet engineering specifications and will perform in a consistent manner in end point use.

The material discussed is organic and is composed of eight ingredients. The lining produced weighs approximately $\frac{1}{3}$ lb and projects 10.3 in^2 of braking surface.

Because the material is organic and is composed of approximately 50% asbestos, another important engineering objective must be met. The production area where this lining is manufactured must have sufficient air quality to meet the Occupational Safety and Health Act standard for asbestos.

750330. A Light Duty Diesel for America? M. L. Monaghan, Ricardo & Co. Engineers Ltd. (United Kingdom); and J. J. McFadden, U.S. Environmental Protection Agency.

This paper describes a study which was carried out to determine the feasibility of the diesel as a light duty power plant for American use.

As a result of a literature survey and a specific configuration study, nine 96 kW diesel power plants were examined in detail. Further examination of the diesel power plants indicated that only the direct injection four-stroke configurations could meet the primary emission targets using current technology.

It was concluded, however, that the diesel engine could provide a viable power plant for light duty vehicles and that considerable improvements in fuel consumption and overall running costs could be obtained.

750331. The Light Duty Diesel Engine for Private Transportation. H. W. Barnes-Moss and W. M. Scott, Ricardo & Co. Engineers (1927) Ltd.

On the basis of European experience, the small high-speed diesel engine is an obvious alternative to the gasoline engine to achieve better fuel economy.

This paper looks at the benefits which would result from the diesel engine in terms of economy, exhaust emissions etc., when applied to American type light-duty vehicles. Areas requiring further development to make the diesel more socially acceptable are also discussed.

Specifications are proposed for two engines of 100 and 150 hp which should satisfy the requirements of private cars, taxis, light delivery vans and recreational vehicles.

It is concluded that the diesel engine can make a significant contribution to fuel economy within moderate exhaust emission legislation.

750332. Emissions and Economy of Four Diesel Cars. Karl J. Springer, Southwest Research Institute; and Ralph C. Stahman, Environmental Protection Agency.

Four diesel-powered passenger cars were subjected to a wide variety of emission and economy evaluations, and the results are presented in this paper. The four production cars included a 1972 Mercedes-Benz 220D, a 1973 Peugeot 504D, an Opel Rekord 2100D, and a Nissan diesel-powered Datsun. Tailpipe emissions were measured by the 1975 Light Duty Federal Test Procedure for gaseous emissions, fuel economy (carbon balance and gravimetric) and smoke. Smoke and gaseous emissions were also measured by chassis dynamometer versions of the 1974 Federal heavy-duty procedures. Odor and related instrumental-chemical measurements were made under seven steady-state and three transient conditions. Odor was measured by a trained panel and the analytical system developed by A. D. Little, Inc., under CRC contract. Noise measurements were taken during SAE driveby and a variety of interior-exterior conditions. The results are compared by category to each other, Federal limits, and to test results obtained by EPA laboratories.

750333. A Diesel Engine for Light Duty Applications. D. E. Larkinson and B. R. Jewsbury, Perkins Engs. Co.

As a result of logical future market analysis, a light duty engine design study has been carried out, for automobile and light commercial vehicle applications. It sets a practical compromise between light weight and low cost, and embodies features not normally found in engines of this type. A newly developed combustion system complies with all likely legislation, as well as improving consumer acceptance of the diesel concept.

750334. Experience with Comprex Pressure Wave Supercharger on the High-Speed Passenger Car Diesel Engine. E. Eisele, H. Hiereth and H. Polz, Daimler-Benz AG (Germany).

After dealing briefly with the mode of operation of the Comprex® pressure wave supercharger, a report is given on its general advantages and drawbacks as well as on experience gained in practical operations on the supercharging system, using a 2.2 dm^3 prechamber passenger car diesel engine. The most important problems which occurred here and the performance and exhaust emission figures resulting from rig and road test measurements are discussed.

750335. Comprex Supercharging of Vehicle Diesel Engines. Peter K. Doerfler, BBC Brown, Boveri & Co., Ltd. (Switzerland).

The purpose of this paper is to demonstrate the superiority of COMPREX® as a supercharging device. Comprex,® a gas-dynamic pressure-wave machine for supercharging vehicle diesel engines in the 100-500 BHP range, uses exhaust gas energy for compressing intake air. Based on a different physical mechanism, it avoids several of the turbocharger's disadvantages. Comprex supercharging gives high torque down to less than 40% of rated speed. Almost instantaneous response combines with significant reductions in acceleration smoke. An increase in maximum compression ratio and efficiency and a wider speed range were achieved by recent development work.

Endurance tests have been successfully performed, and the system has been redesigned for smaller dimensions and adapted to production requirements.

750336. Development of a High Speed Four-Cylinder Diesel Engine Under Consideration of the Existing Machinetools Equipment for the Production of the Gasoline Engines. H. Weitzel, Adam Opel AG.

This paper deals with the development of a light high speed diesel engine at low cost for saloon cars with an operating cost and driving performance comparable with the gasoline engines. The development centered around using existing manufacturing techniques as used on gasoline main engine components and engine cylinder blocks for the diesel engine. Initial design and development investigations and design and development of the production engine are discussed.

The work has resulted in the production of the 2.1 liter diesel engine, installed in the Opel Rekord car with 1.210 kg curb weight. With its 60 hp performance and 12.0 mkp torque, the engine gives the car a sufficient driving characteristic and reserves a good market share, especially in those countries where the diesel fuel is remarkably cheaper than petrol.

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750337. Scheduling Injection Timing for Reduction of Diesel Emissions. I. M. Khan and A. C. Green, Cav Ltd. (United Kingdom).

This paper deals with the requirements for scheduling injection timing as a function of speed and load for high-speed light-duty diesel engines and also for larger diesel engines. A combined speed and load timing device developed for the CAV DPA pump is presented. Work on two passenger cars powered with swirl chamber diesel

engines initially having standard DPA pumps and later fitted with pumps incorporating the timing scheduling device is then described and discussed. Some examples of timing scheduling requirements for larger direct injection engines are also given. It is shown that injection timing scheduling is essential to minimize gaseous and visible emissions while satisfying the noise and fuel economy aspects of engine or vehicle performance.

750338. Design in a Textile Revolution. Colin G. Neale, Chrysler Corp.

Interior design in automobiles has come a long way in 70 years—from stiff saddle leather and protective dust coats to plush jacquard velour seat coverings and recycled trunk linings. Technology, history and the individual buyer have all affected change. Significant dialogue between the textile industry and automotive designers is fairly recent —within the last decade. Increased market demands in the automobile industry have provided impetus for yet another surge in the ever on-going textile revolution. The influence of both component application and material construction has resulted in bold new colors and textures for seatcovering, headliners and floor coverings. Decorative and tactile capabilities of today's new synthetic materials have created a broad spectrum of possibilities for the future of interior design, including computerized interpretation of fabric and color combinations.

750340. Engineering Requirements for Automotive Textiles. John B. McCallum, Ford Motor Co.

Textiles, particularly fabrics, are changing rapidly in composition and construction for automotive interiors. To meet these changes, the development of realistic engineering material requirements are necessary. To provide a durable, functional and competitive product, a textile specification and the tests it employs, must be based on the end item design and application, as well as the textile's composition and construction.

Over the past twenty years, synthetic fibers have replaced natural fibers with resultant increases in the physical properties and durability of interior trim. The future holds still more changes due to diminishing petroleum supplies from which most synthetic fibers are made. Future automotive textiles will be based on more efficient use of synthetic fibers, and possibly on the development of new fibers from cellulose or other natural compounds as a base.

750343. Conservation of Resources—Organic Surface Coatings. John B. Hemwall, Inmont Corp.

With the trend toward decrease in demand rather than an increase in supply, the present petroleum resources can fill the need of the automobile production industry, at least through 1975. Assuming, furthermore, that environmental and energy conservation legislation will continue pressuring industry, the automobile surface coating industry is taking steps to devise new methods of production to comply with these demands while still maintaining efficiency.

Although the rising cost of other raw materials must also be considered, the surface coating industry foresees the use of water-based topcoats and primers as both an economically and environmentally safe technique. If humidity control cost seems to be more expensive than planned, powder-based coats and new curing methods could prove to be even more efficient.

750344. Glass Materials: 1974–1980. Richard F. Sperring, PPG Industries.

The glass and fiberglass industries are playing an increasingly important role in the production of automobiles. These industries depend upon a regular and dependable supply of raw materials, adequate energy, and the means to transport raw materials as well as finished products. This paper examines these factors and discusses the ability of the glass and fiber-glass industries to meet the needs of the automotive industry through 1980.

750345. Epoxies and Urethanes—Changing Times Breed New Products. Justin C. Bolger, Amicon Corp.

This paper reviews several new epoxy and urethane products and bonding processes developed in response to recent power and materials shortages, price increases, and new worker safety or environmental protection legislation. These new developments include MOCA and TDI-free urethane elastomers, low-solvent liquid epoxies, new epoxy powder coatings, epoxy seam filler to replace lead on passenger car bodies, and high speed, on-line, cure and fixturing methods. Each of these new products or processes represents an important advance in addition resin curing agent technology.

750346. HEI - A New Ignition System Through New Technology. Gerald O. Huntzinger and Gerald E. Rigsby, Delco-Remy Div. General Motors Corp.

A new high-energy, electronic ignition (HEI) system with substantially improved performance and durability has been developed for automotive gasoline engines. All components of the system are integrated within the distributor, and no scheduled parts replacement or adjustment of system components is required. The requirements of system performance and durability, which guided the development of the new system, are outlined. New concepts, materials, and technology used in the design and development are illustrated and explained. A discussion of the operation and limitations of both breaker-operated and transistor systems explains the need for dwell time control and coil primary current regulation. These are new control functions incorporated in the HEI system which result in reduced component size and power dissipation which is essential for the integral design.

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750347. The Texaco Ignition System—A New Concept

for Automotive Engines. R. E. Canup, Texaco Inc.

The Texaco Ignition System (TTIS) is a high frequency system with a bi-directional spark current, the duration of which is a function of crankshaft rotation rather than time. The spark current characteristics differ drastically from those of conventional discharge systems and, as a result, current flow through the plug gap can be maintained under extremely turbulent conditions. Being essentially a constant current device, it prevents excessive plug current flow during initial gap ionization, providing a good plug life; yet it has high average current to increase fuel ignition probability.

The system, developed primarily for use with stratified charge engines, has also been shown to have characteristics which improve the performance of premixed charge engines operated under severe conditions, in order to reduce exhaust emissions, improve driveability and increase fuel economy.

TTIS is of solid state design, and both the spark timing and spark duration are controlled by use of digital logic circuitry.

750348. Programable Energy Ignition System for Engine Optimization. Richard W. Johnston, John G. Neuman and Paul D. Agarwal, Res. Labs., General Motors Corp.

Emission control requirements have prompted optimization studies of many engine parameters, such as engine geometry, fuel preparation, and ignition. This paper describes an experimental ignition system which permits these studies with a spark that has an adjustable power level and independent programable arc duration.

This new ignition system uses inductive-discharge to strike the arc and, together with transformer action, sustains the arc from a single coil for any duration. Its principal features are: (1) programable arc duration, (2) high arc current for full arc period, (3) fast voltage rise, (4) low average battery current drain, (5) no intermediate power supply, and (6) since it uses inductive storage, it can be integrated into present electronic systems if the need is proven. Limited test results are presented to show the effect of arc duration on engine operation.

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750349. Plasma Jet Ignition of Lean Mixtures. Floyd A. Wyczalek, Daniel L. Frank and John G. Neuman, Engrg. Staff, General Motors Corp.

The development of a plasma jet ignition system is described on a 4-cyl, 140 in^3 engine. Performance was evaluated on the basis of combustion flame photographs in a single-cylinder engine at 20/1 A/F dynamometer tests on a modified 4-cyl engine, and cold start emissions, fuel economy, and drivability in a vehicle at 19/1 air fuel ratio.

In addition to adjustable engine variables such as air-fuel ratio and spark advance, system electrical and mechanical parameters were varied to improve combustion of lean mixtures. As examples, the air-fuel ratio range was 16-22/1, secondary ignition current was varied from 40 to 6000 mA, and plasma jet cavity and electrode geometry were optimized.

It is shown that the plasma jet produces an ignition source which penetrates the mixture ahead of the initial flame front and reduces oxides of nitrogen emission, in comparison to a conventional production combustion chamber. The reduction in oxides of nitrogen is attributed to decreased gas residence time at high temperatures and a lower gas temperature history.

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750350. Design, Function, and Application of Ionizing Gaps for Ignition Systems. Harald Mauch, Robert Bosch GMBH (West Germany).

Misfiring of engines with fouling spark plugs is caused by a loss of ignition energy in the deposits of the spark plugs. This loss of energy can be avoided and a steep ascent of voltage achieved by connecting an ionizing gap with suitable breakdown voltage in a series close to each of the spark plugs. Vehicle application requires ionizing gaps with high stability of breakdown voltage over life time. Design and performance of the new BOSCH Ionizing Gap are explained.

750351. EFI Prechamber Torch Ignition of Lean Mixtures. F. A. Wyczalek, J. L. Harned, S. Maksymiuk and J. R. Blevins, Engrg. Staff, General Motors Corp.

This paper describes the development of a prechamber-type torch ignition system on a modified 4-cyl, 140 in^3 engine. The prechamber consists of a blind cavity coupled to the main chamber with an orifice. Fuel is supplied to the prechamber with an electronic fuel injector and this mixture is ignited by a spark plug. The prechamber produces an ignition torch which ignites a main chamber that is supplied with a lean mixture carbureted in the conventional manner. The performance of this combustion concept was evaluated on the basis of vehicle driveability, exhaust emissions, and fuel economy in a 3000 lb weight class vehicle.

In addition to adjustable engine variables, such as air fuel ratio and spark advance, electronic fuel injection and mechanical parameters were varied to improve combustion of lean mixtures. As examples, the carbureted main chamber air fuel ratio was explored from 18-26:1, the prechamber fuel injection rate was varied by modulating injector pulse width and fuel injection timing was evaluated during the exhaust, intake and compression strokes.

The electronic fuel injection torch ignition concept produces an ignition source which penetrates and inflames the lean mixture in the main chamber and increases the rates of combustion substantially. Typical road load spark advances are about 12 deg(MBT) before top center, compared to 40 deg for a stock engine. This combustion process reduces carbon monoxide and oxides of nitrogen emissions, in comparison to a conventional combustion

chamber. The reduction in carbon monoxide is attributed to improved cold starting with less carburetor choking, and the burning of lean mixtures in the main chamber. The reduction in oxides of nitrogen is attributed to the lower combustion temperatures of the lean mixtures.

750352. Off-Stoichiometry Operation of an SI Engine—A Model of Formation and Control of Nitric Oxide. G. G. Lucas and K. S. Varde, Loughborough Univ. of Tech. (United Kingdom).

The highest concentrations of NO appear in the exhaust of a spark ignition engine when it is operated slightly on the lean side of stoichiometry. A suggested method of control therefore is to run the engine at an off-stoichiometric air/fuel ratio where the nitric oxide emission is low. Operating the engine in the fuel rich region entails high emissions of carbon monoxide and unburned hydrocarbons and is not compatible with the idea of conserving fuel energy. Therefore, it is advisable to run the engine in the lean mixture region.

A number of models have been developed in the past to predict NO emission levels by the use of the rate kinetic reactions:

$$N_2 + O \rightleftarrows NO + N$$
$$N + O_2 \rightleftarrows NO + O$$

In these the oxygen atom concentration has been assumed to be that at equilibrium and this has been justified on the basis that the rate of heat release is greater than the rate of NO formation. However, in the lean mixture range (fuel/air equivalence ratio $\simeq$ 0.80:0.60) experimental observations have indicated higher concentrations than those predicted by such models. Now it is known that the oxygen atom concentration in the combustion chamber of an engine can be higher than the equilibrium concentration, particularly in the lean mixture region. Such higher concentrations of [O] can yield higher concentrations of NO.

This paper describes a model which takes account of this super-concentration of oxygen atoms in the flame front in order to predict NO emission levels. Comparisons are made with measured results and the agreement found to be good. The combustion duration period is considered as a critical parameter in the control of NO in the lean mixture range.

750353. Potentiality of the Modification of Engine Combustion Rate for NO_x Formation Control in the Premixed SI Engine. Hiroshi Kuroda, Yasuo Nakajima, Kunihiko Sugihara and Yasuo Takagi, Nissan Motor Co., Ltd.

In order to study the potentiality of the modification of the combustion rate for NO_x formation control in the spark ignition (SI) engine, the authors first developed a new mathematical model by assuming the stepped gas temperature gradient in the cylinder. The predicted results from this new mathematical model show good coincidence with the experimental data.

Second, the authors discuss the effects of the modification of the combustion rate on NO_x formation using the new mathematical model. It was concluded that NO_x formation in the premixed SI engine would be essentially determined by the specific fuel consumption only, regardless of any modification of the engine combustion rate.

750354. Significance of Burn Types, as Measured by Using the Spark Plugs as Ionization Probes, with Respect to the Hydrocarbon Emission Levels in S.I. Engines. William G. Rado and Wayne J. Johnson, Ford Motor Co.

A method has been developed for the acquisition and analysis of electrical signals, called combustion signals, from the cylinders of spark ignition engines based on using the spark plugs as ionization probes.

A correlation has been established between the simultaneously recorded combustion and cylinder pressure signals based on which combustion signals could be used to identify three types of burns. These burn types were called good burns, slow burns, and misfires.

The statistical occurrence of these burn types was also correlated with the hydrocarbon exhaust emission levels for engines operating under dynamometer simulated decelerations and for engines operating with various amounts of exhaust gas recirculation (EGR). Both production and experimental engines have been investigated.

It was found that during both decelerations and operation with EGR, the degradation from good burns followed the same pattern irrespective of engine type. Good burns gradually turned into slow burns, then into misfires as decelerations became more severe or as the EGR rate was increased.

Based upon the data from the various degradation measurements, slow burns and misfires were found to contribute 3-13 and 18-24 times the amount of hydrocarbons in the exhaust.

750355. The Effect of Engine Design Parameters on Combustion Rate in Spark-Ignited Engines. J. Mayo, Combustion Engrg. Dept., Ford Motor Co.

Studies have, by calculation, shown that fast combustion rates tend to produce low NO_x levels. Their analysis has been partially confirmed by actual engine data on a highly turbulent fast burn engine. Thus, an experimental program was conducted to develop quantitative data on the effect of some of the engine design features that are known to have a significant influence on combustion rate.

The effect of five engine design factors on combustion rate was determined. Burn time was measured on 17 different engine configurations, each configuration containing different design levels of the five design factors. Burn time measurement was also made on a carbureted highly turbulent bowl-in-piston fast burn engine with a centrally located spark plug. Significant reduction in burn time from a production combustion chamber was

achieved by application of the design factors, but the fast burn rates of the carbureted fast burn engine could not be reached.

The effects of burn time on cyclic variation, ignition delay time, rate of pressure rise and emissions were also examined. Decreasing burn time resulted in increased rates of pressure rise and hydrocarbon emissions and reduced cyclic variation and ignition delay time. Reduction in NO_x emissions was noted when burn time was decreased while operating with exhaust gas recirculation.

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750356. Describing the Driver's Work Space: Eye, Head, Knee, and Seat Positions. Ronald W. Roe, General Motors Corp.

The SAE Controls Reach Study provided the opportunity to obtain a considerable amount of driver work space data in addition to hand and foot reach. A side-view film recording was made of each test subject assuming a driving attitude and looking straight ahead. Of concern were locations for the driver's eyes, top of head, back of head, knee, and seat.

These data were combined with other data previously reported to develop tools that will aid the designer in describing space and comfort requirements for seated drivers and passengers in automotive packages. Fixed-seat eye ellipses, head locations, shin-knee locations, and preferred seat positions are described.

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750357. Controls Reach — The Hand Reach of Drivers. David C. Hammond, David E. Maurer and Leo Razgunas, Environmental and Safety Research Office, Ford Motor Co.

This report describes a series of three-dimensional boundaries beyond which it is confident that at least 95% of the drivers of the United States population can reach and operate a simple three-finger-grasped control. Consideration is given to a reach task when drivers are restrained by a nonextending shoulder belt and when they are unrestrained. The background data used to develop these boundaries were collected in the SAE Controls Reach Study in June-August 1971 in which over 250 subjects were measured in three test fixtures representing a sports car, passenger car and a heavy truck. Finger-grasped reach was recorded to 40 locations in front of the driver.

750358. Restraint Systems: A Human Engineering Evaluation. W. E. Woodson, Man Factors, Inc.

Consistent complaints of discomfort, confusion and inconvenience as reasons for ignoring seat belts prompted this study. Focus of the study was to identify specific complaints, make design modifications where indicated, and subject the optimized configuration to consumer scrutiny. Included in the paper are discussions of problem analysis, methods of evaluation, experimentation and testing of findings in controlled situations.

Initial surveys indicated a correlation between design features and general complaints. To improve the design, various factors were considered, including range of users (including those with manipulation problems), preferences in buckle, latchplate and button design, and tension limits. An optimized system resulted.

Six vehicle systems, including two optimized belt designs and two semi-passive designs were tested in various trials. The optimized systems rated consistently higher, indicating that consumer complaints can be interpreted and translated into design improvements.

750359. Methods for Determining Unobscured Areas on Instrument Panels. Ronald W. Roe, Design Staff, General Motors Corp.

This paper describes two methods for determining areas on the instrument panel that are visible through and around the steering wheel rim, hub, and spokes. Both methods are design tools that can be used early in the development of new instrument panels to insure that critical displays will not be obscured.

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750360. Study on Japanese Driver Eye Position. Toshiro Ishida and Masanori Matsuno, Japan Automobile Res. Inst., Inc.

The purpose of this study is to measure eye position of the Japanese driver. Test cars were three Japanese-produced passenger cars. Subjects were 264 males and 53 females.

Eye range contours of various seatback angles were drawn and were compared with SAE J941c's. In side view the eye position for Japanese drivers is somewhat to the rear and lower than that of American drivers. In plan view, the minor axes of eyellipses of Japanese drivers are shorter than those of SAE eyellipse.

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750362. A Research Design to Collect Data for a Second Generation Eyellipse. James M. Miller and Susanne M. Gatchell, University of Michigan.

Current automotive design practices related to driver visibility are based on static laboratory studies of mostly straight ahead viewing that were conducted by Meldrum and others beginning in 1962. These individual studies have never been replicated either in the lab or in actual driving situations to determine the validity of their procedures.

After a thorough review of the literature related to driver eye location and a statistical analysis of previous static eye location data, an experimental design is proposed to determine dynamic eye location distribution characteristics. This design will provide information on: (a) the relationship of static anthropometric measurements to dynamic eye location; (b) the difference between dynamic on-the-road eye location versus static in-the-lab eye location distributions: (c) the effect of different types of vehicle seating package parameters on eye location;

and, (d) a validation of previous static eye location studies.

The data obtained from the proposed experimental design could be used to verify or replace the SAE Eyellipses. Also, it would allow for the development of a mathematical model that will describe eye positions during the driving task as a function of package variables, driver anthropometry, and target viewing angles.

750363. Comparison of Eye Fixations of Operators of Motorcycles and Automobiles. Rudolf G. Mortimer and Craig M. Jorgeson, Highway Safety Research Institute, The University of Michigan.

The eye fixations were measured of two motorcyclists who drove a motorcycle and later an automobile on two-lane rural roads at about 45 mph, in daytime. The effects of road edge delineation, road geometry, oncoming vehicles, and whether the drivers were controlling a motorcycle or an automobile were evaluated in terms of the manner in which the drivers used their eyes to obtain visual information. The results indicated that most of the drivers' attention was directed within 5° of the forward line of sight, but on curves, the drivers' eye fixations shifted in the direction of the curve. When an oncoming vehicle appeared, the drivers spent a substantial proportion of the viewing time looking at it periodically. The mean duration of glances were longer for these drivers when operating a motorcycle than an automobile. When operating the motorcycle there were relatively more glances made closer to the vehicle than when driving the car, suggesting that motorcyclists are more concerned with irregularities, composition and frictional characteristics of the pavement surface. The motorcycle riders also tended to view along the right side of the lane more than when driving the car. Comparisons made between the eye fixations of these motorcyclists when driving an automobile and those of other drivers of an automobile indicated considerable agreement, except that the motorcyclists attended more to oncoming vehicles.

The results of the study are used to infer the type of distribution of illumination required from motorcycle headlamps for night driving. The beam pattern of motorcycle headlamps should be somewhat different than that provided automobile drivers, particularly in that good foreground illumination is required for visibility of the surface characteristics of the pavement. The beam should also emphasize the right edge of the road.

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750364. (SP-393) **Survey of Electronic Displays.** J. F. Nolan, Owens Illinois Technical Center.

This paper presents a survey of the various types of electronic displays that are available now or are being investigated in research laboratories. The survey is limited to small or medium sized displays which might be suitable for automotive dashboard displays. Included in the survey are light emitting diodes, planar gas discharge, incandescent, vacuum fluorescent, electroluminescent, and liquid crystal displays, as well as some other types of displays which, although not commercially available at present in quantity, are being actively investigated in research laboratories. The discussion includes topics such as the distinction between active and passive displays and the advantages and limitations of each type, the principles of operation of the various types of displays, and their electrical and optical characteristics.

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750365. (SP-393) **Electronic Display Systems in the Automobile.** Myron U. Trenne and John J. Stephan, General Motors Technical Center.

This paper presents automotive requirements for electronic digital displays. Light emitting, light reflecting, and light absorbing technologies are considered independently. The drive circuits, interconnects, and dimming aspects are considered as part of automotive requirements.

Several digital display system techniques fundamental to an effective display are presented in terms of examples for speed and fuel displays.

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750366. (SP-393) **Electronic Display Applications in Instrument Panel Design.** H. Nissley and R. J. Boike, Ford Motor Co.

Electronic displays, or more precisely, solid state and plasma displays controlled electronically are becoming increasingly evident in most segments of our commercial environment. The exception to this general pattern is the automotive vehicle where only a small number of applications have appeared.

This paper deals with the application of electronic displays in the instrument panel design process. More specifically, it will discuss how electronic displays can assist in dealing with the major design problems in this area of the vehicle.

The paper will also cover other advantages of electronic displays in terms of the serviceability, reliability and overall appearance of the instrument panel area.

In summary, the purpose of this paper is to assist personnel involved in instrument panel design to utilize this new technology more effectively as applications broaden in our industry.

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750367. (SP-393) **Techniques For Driving Digital Displays.** George R. Seaton and David A. Wayne, Dionics Inc.

With the growing importance of digital electronics, the need for methods for displaying digital information has grown. Several technologies for information display devices presently exist or appear to be likely prospects for future commercial development. The systems designer is often faced with the problem of providing an electronic interface between the digital system and the display device. This paper sets forth solutions to the problem of designing the interface electronic circuitry. Particular

attention is paid towards integrated circuits available for this application.

750368. (SP-393) **Bosch Electronic Fuel Injection with Closed Loop Control.** I. Gorille, N. Rittmannsberger and P. Werner, Electronics Div., Robert Bosch GmbH (Germany).

The paper describes an electronic fuel injection system with improved performance. This is achieved by basic system considerations as well as by sophisticated electronics design making use of custom designed bipolar integrated circuits. By using an oxygen sensor, it is possible to detect the stoichiometric mixture and to use a closed loop control to meet the proposed United States Federal Emission Standards of 1978. The basic electronic design, the closed loop control, and the oxygen sensor are described.

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750369. Closed-Loop Electronic Fuel and Air Control of Internal Combustion Engines. John Camp and Todd Rachel, Bendix Corp.

Utilizing a closed loop EFI system with an oxygen (Lambda) sensor as a feedback element, techniques are demonstrated to expand the A/F operating range up to 10% from a stoichiometric calibration.

Fuel injection timing techniques, such as "simultaneous double fire," are presented which further enhance the transient engine response of EFI vehicles.

A closed loop air control system operating with the EFI system is discussed. This system has resulted in improved idle-speed control during both cold-and warm-engine operating conditions.

750370. (SP-393) **Electronic Optimizer Control For I.C. Engine: Most MPG For any MPH.** Paul H. Schweitzer, Optimizer Control Corp.; and Carl Volz, Electrical Engineering Dept., Penn State University.

The Optimizer is an electronic control system that keeps the engine in tune all the time by adjusting its setting continuously for best fuel economy several times each second.

In contrast to the conventional programmed controls, the Optimizer works on the closed-loop principle in which the output influences the input. It has been applied to setting the spark timing and air-fuel ratio in otto engines and injection timing in diesel engines.

Optimizer control is applicable to the adjustment of any setting in any prime mover: right-left, up-down, clockwise-counter clockwise, which influence the power output.

The dramatic advance in microelectronics in the last few years permits the application of Optimizer controls to conventional automobile engines at an amazingly low manufacturing cost.

750371. (SP-393) **Closed Loop Carburetor Emission Control System.** R. A. Spilski, Chevrolet Engineering Center; and W. D. Creps, Research Labs., General Motors Corp.

Electronic control logic and system components are described that are used with a venturi carburetor to accomplish the fuel metering required in a closed loop emission control system. Special open loop functions are used because of the nature of the venturi carburetor and the warm-up characteristics of the three-way catalytic converter and exhaust gas sensors. Strip chart recordings illustrate the dynamic characteristics of the electronic control logic, and emission test results with a low mileage three-way converter are set forth.

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750373. Conductive Ceramics for Use in the Na-S Battery. T. J. Whalen, Scientific Res. Staff, Ford Motor Co.

Ceramics with compositions in the systems Na_2O-Li_2O-Al_2O_3 have been investigated for application in the Na-S battery. The mechanical and electrical properties of these ceramics have been determined and some optimum compositions have been tested in Na-Na cells. The influence of sintering temperature and time on the properties of these ionically conductive ceramics is discussed.

750375. The Function and Performance of Beta Alumina in Sodium/Sulphur Cells. M. D. Hames and J. H. Duncan, British Railways Board.

The development of beta alumina ceramic in terms of its function as an electrolyte and physical separator in sodium/sulphur cells is traced. Data which illustrate some of the problem areas associated with this material are discussed. The function of β alumina as a physical separator, and as a low resistance material is developed. In the performance area, the resistive effects, the electronic breakdown and the life of the electrolyte are discussed in detail.

The authors reach the conclusion that the optimum performance of the β alumina electrolyte is dependent on its composition.

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750376. An Engine Oil Formulated for Optimized Engine Performance. W. H. Richman and J. A. Keller, Mobil Research and Development Corp.

A light viscosity engine oil formulation has been developed based on an extension of the synthesized hydrocarbon fluid (SHF) lubricant technology presented in a recent SAE paper by B. J. Miller, et.al. Utilization of these base materials has enabled the formulation of a product, designated XRN 1669, which provides a significant improvement in both fuel economy and oil consumption control. A combined improvement in these two performance areas has not been attainable in the past with conventional mineral oils. In addition to fuel and oil economy, other critical areas of performance are inves-

tigated, including engine cleanliness, wear protection and cold starting capability, as well as ONRI and exhaust emission effects.

The superior performance of XRN 1669 compared to premium quality multiviscosity mineral oil products is documented in extensive laboratory, engine and field tests.

750377. Automotive Fuel Savings Through Selected Lubricants. William B. Chamberlin and Thomas J. Sheahan, Lubrizol Corp.

A vehicle track test showed increased gasoline engine fuel economy under both cold start and warm engine conditions using combinations of selected engine oils and power train lubricants. The engine oils, automatic transmission fluids and rear axle lubricants were chosen based on engine dynamometer and road simulator screening tests. Motored and fired engine dynamometer tests were used to evaluate engine oils on friction horsepower and fuel consumption. Other tests were used to examine automatic transmission fluids and gear lubricants on fuel consumption, economy and efficiency.

750378. Predicting the Shear Stability of Multigrade Engine Oils from Bench Tests. R. M. Stewart, Gulf Res. & Dev. Co., Gulf Oil Corp.; and M. L. McMillan, Res. Labs, General Motors Corp.

Engine oil shear stability data from six U.S. and two European car fleets have been obtained using 13 ASTM Reference Oils. These data were obtained to serve as the basis for evaluating the ability of laboratory tests to predict the shear stability of multigrade engine oils in service.

Four types of laboratory bench tests and three different laboratory engine tests were evaluated in an initial program. Based on the results of these tests, additional programs are under way using diesel injector rigs and single-cylinder motored engines in an attempt to improve correlation with the field data. A tapered bearing shear stability tester, not included in the initial program, is also being evaluated. In addition, some recent shear stability activities by the Cooperative European Council are summarized briefly.

Discussion: Theodore W. Selby, Savant, Inc.; and Harold Shaub, Exxon Research and Engineering Co.

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750379. A Test Procedure for Evaluating Temporary-Shear Loss of Engine Lubricants. R. L. Stambaugh and R. J. Kopko, Rohm and Haas Co.

Temporary shear loss characteristics of multigraded engine oils were measured in a newly developed engine oil pump rig. Correlations of the results with high pressure capillary viscometry data indicate that the test apparatus generates shear rates in the range of $2\text{-}3 \times 10^5\ s^{-1}$. One advantage of this technique over similar mechanical approaches is that the test rig causes virtually no permanent shear degradation. Test results are reported for a variety of polymer types, and the relationship of permanent and temporary shear losses is discussed.

750381. Automatic Transmissions for Passenger Coaches. R. H. Schaefer and D. L. Robinson, Detroit Diesel Allison Div., General Motors Corp.

Since the first passenger coaches were built in the early 1900's, coach manufacturers have sought better and better engine-transmission combinations and arrangements in order to improve performance, operation, and passenger convenience. As the coach industry entered the 1970's, it became increasingly obvious that a need existed for a new transmission to replace those of the old V-family that provided the bulk of the market for the past 40 years.

Recognizing the need, Detroit Diesel Allison developed two new transmissions, the HT 740 and the V730, for the coming generation of coach applications. These two units permit a number of engine-transmission-axle arrangements and are adaptable to diesel and gas turbine engines. It is anticipated that these units will find wide usage in new coaches currently under development.

750382. The Variable Ratio Master Cylinder—A Description of Its Function and Operation. R. L. Nigg, A. W. Palmer and R. F. Green, Borg & Beck Div., Borg-Warner Corp.

The concept of an improvement in work utilization by modification of the hydraulic brake master cylinder currently employed in production automotive vehicles is presented. The improvement, which is in the form of a variable ratio master cylinder having the advantage, among others, of reducing intermediate and final brake pedal efforts without the need for an external assist, is explained.

The function, description, operation, vehicle need, history, methods of evaluation, and advantages and disadvantages of the variable ratio master cylinder are discussed.

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750383. Brake Fluid Functionability in Conventional and Anti-Skid Systems in Arctic Conditions. David Brown and Colin Harrington, Res. Lab., Burmah Castrol Co. (United Kingdom).

The effect and description of vehicle braketests performed under conditions of low ambient temperature and the evaluation of the effect of brake fluid viscosity, under these conditions, on brake system performance. Vehicle braking tests were performed within the arctic circle.

750384. Hydraulic Power Brake Booster for Small Cars. Kenneth B. Swanson, Midland-Ross Corp.

This paper describes a hydraulic power booster which has been developed for small cars and which utilizes the power steering pump as a power source. The unit provides higher master cylinder pressures and lower pedal efforts to aid in meeting regulations set by the National Highway

Safety Administration. In addition, the booster configuration described provides a smaller and lower weight package than similar units and provides a ratio change feature.

Details of the design and operation characteristics of the Midland-Ross Ultrastop hydraulic power brake booster are given including concentric piston design ratio changer.

750385. Stepped Bore Master Cylinder—A Way of Improving Dual Brake Systems. Ante Larsson and Lars Larsson, AB Volvo.

It is now several years since most passenger vehicles were provided with a dual circuit braking system. The increased safety which has been obtained by this, has the disadvantage of extra pedal movement and increased pedal force which is then required when one circuit has broken down. Besides the deterioration in braking performance it can give the driver a shock. By replacing the tandem cylinder of conventional type hitherto used with a new type, these disadvantages have practically been eliminated.

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750387. Waste Oil Management From Sump to End Use — A Status Report. Peter B. Lederman, U.S. Environmental Protection Agency.

About 2.5 billion gallons of waste oil are generated annually in the United States. About half of that is spent lubricating oil. This oil has value and is recoverable. Recovery practices are discussed and evaluated.

750388. A Joint Venture of Recycling in Plant Waste Oils. Joseph A. Oster, Chrysler Corp.; and George T. Booth, Jr., Booth Oil Co., Inc.

With the so called "Energy Crisis" upon us, the cost and availability of plant lubricants have become of prime importance to management. Although the re-refining of waste oils is far from a new concept, it is just now being generally accepted as a means of reducing costs, while resolving liquid waste disposal problems and assuring a guaranteed source of supply.

750389. Passive and Active Restraint Systems—Performance and Benefit/Cost Comparison. L. M. Patrick, Wayne State University.

Five different restraint systems—mandatory harness, airbag + 20% lap belt usage, airbag, passive three point harness, and torso and knee bar—are analyzed for fatality and injury reduction, benefit/cost ratio, and cost-effectiveness. The mandatory harness is superior to the others in all comparisons with approximately 100,000 lives saved over the first 10 years which is about twice as many as would be saved by the other systems. A major advantage of the mandatory harness is that practically all of the vehicles are equipped while the other systems will require 10 years for complete installation.

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750390. Why Your Best Life Insurance Is a Passive Restraint. Jack E. Martens, Allstate Insurance Company.

It is becoming apparent that some safety devices are performing their desired function rather well while others are not. The one quality that all the better designs have is they require no action on the part of the occupant to perform their safety function in the event of a crash, that is, they are passive. Presently, the most viable passive restraint is the air bag. It inherently offers convenience and reliability characteristics which will appeal to the general public. Active restraints, such as the adjustable head restraint, ignition-interlock and lap/shoulder belt have consistently shown by their usage figures that they are unacceptable to the public.

750391. Passive Versus Active = Life Versus Death. A. B. Kelley, Insurance Institute for Highway Safety.

Throughout the history of public health progress, including progress in the field of crash protection for motor vehicle occupants, passive approaches have been associated with great and lasting effectiveness in terms of lives saved and injuries reduced. Active approaches, on the other hand, have been associated with far lower levels of payoff in the prevention of death and injury when humans come into contact with the potential hazards in their environments.

Where motor vehicle standards have left them the latitude, auto manufacturers too often have chosen active rather than passive approaches to meeting those standards—with predictably damaging consequences for their customers. It is essential that the public understand the basic conceptual differences between the two approaches, and be brought into the decision-making process before motor vehicle safety standards are met in ways that deny motor vehicle occupants the more effective levels and breadths of protection afforded by passive approaches.

750392. Belts, Bags, and Medicines: Application of a Medical Treatment and Prevention Model for Automobile Occupant Protection. E. F. Domino and D. F. Huelke, University of Michigan Medical School.

In that restraint systems can be viewed as medicines for the prevention of injury or death, some pharmacological approaches to the occupant restraint discussions are presented. Traffic morbidity and mortality are presented as endemic disease processes and pharmacological countermeasures in terms of testing dose rates, LD 50, side effects, informed consent and multiple drug usage, and federal drug approval are described.

750393. An Objective Analysis of the Protection Offered by Active and Passive Restraint Systems. P. Ventre and J. C. Rullier, Direction des Recherches et Développement de la Régie Nationale des Usines RENAULT; and C.

Tarriere, F. Hartemann and A. Fayon, Laboratoire de Physiologie et de Biomécanique—Association PEUGEOT-RENAULT.

Current comparisons between active and passive restraint systems are still subjective and emotional. Statistical data, accident surveys, theoretical studies, and crash test results allow a technical analysis. Taking into account technological problems related to various devices and considering their economical incidence and their efficiency, it is possible to form an objective opinion. Conclusion is that the different principles of restraints are not opposed, but appear as successive steps of a same evolution.

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750394. Occupant Protection . . . Back to the Basics. Philip D. Vrzal, Chrysler Corporation.

This paper provides a structured but simple reorientation to the basics of occupant protection with restraint systems. A general assessment of the various kinds of restraints as they relate to those basics at this point in time follows. The evaluation of typical restraints and restraint concepts include: conventional belts, energy-absorbing pads and panels, conventional air cushions, full crash mode air cushions, passive belts and belt improvements, and inflatable belts. Expanding the basics to include other than technical considerations is also briefly discussed.

750395. Determination of Restraint Effectiveness, Airbag Crash Test Repeatability. John Versace and Roger J. Berton, Ford Motor Company.

Thirty-three airbag-equipped Mercury cars were crash tested at three different test laboratories in order to determine the repeatability of test results in the proposed FMVSS 208 procedure. Nine Hybrid-II crash dummies were used. There were significant inconsistencies in results from the three testing agencies; by comparison, the different dummies caused little or no difference in test results; there was a large component of test variability due to uncontrolled and generally unknown factors operating in each test crash.

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750396. Analysis of Occupant Restraint Systems. David E. Martin and Louis C. Lundstrom, Environmental Activities Staff, General Motors Corporation.

Restraint systems are either active or passive. If active (usually safety belts), they offer good individual effectiveness and low cost, but because of low use rate, have low benefit on the societal (national) level. Passive systems eliminate dependency on use rate, therefore promise high societal benefit, but usually at high cost in dollars and/or convenience. Such restraints, whether active or passive, serve primarily to augment passive protection already offered in passenger cars like the energy absorbing column, high penetration windshield glass, etc., which accident data indicate can provide a basic level of protection, and do help reduce the effects of a collision.

750397. Development of Police Car Brake Standards. G. R. Wynne, Los Angeles Police Dept.

In 1957 the Los Angeles Police Department recognized the need for improvement in braking systems on police emergency vehicles. From that date to the present time, there has been an ongoing program of testing and evaluating brake linings and braking systems to provide fade-free balanced braking. As a result of this program, substantial improvements have been made in developing brake characteristics which point the way for police vehicle braking standards.

750398. A Braking Efficiency Test Technique. Christopher B. Winkler and Robert D. Ervin, University of Michigan.

This paper provides a method whereby vehicle stopping performance can be specified, measured, and compared independently of the test surface. The method provides for an independent measure of the prevailing friction potential of the test surface which is used to normalize the measured stopping performance of the test vehicle. The concept presented is tailored toward a safety argument and toward rulemaking as a potential adaptation to braking effectiveness requirements which currently exist. A new mobile tire dynamometer, developed for this program, is discussed, as are the results of a demonstration test program.

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750399. Is the Proposed Federal Standard for Brakes Adequate for Police Patrol Vehicles? Jared J. Collard, National Bureau of Standards.

In 1972, the National Bureau of Standards surveyed 530 police departments to determine what was wrong with their patrolcars: 449 departments responded to the survey. Thirty-two percent of the respondents, a plurality, identified brakes as the most dangerous feature, and 36% identified it as the system most in need of standards. Ninety-four percent of the respondents rated their patrolcar brakes excellent to satisfactory at speeds under 70 mph (113 kph), but 25% rated them poor over 70 mph. While the new Federal Motor Vehicle Safety Standard 105–75 may improve the brake systems for patrolcars for routine, low speed use with frequent applications, it will be necessary to continue testing patrolcar brakes under severe driving conditions to assure reliability at high speeds.

750400. Cab Condition—Heating and Cooling—Heavy Duty Truck and Off-Highway Equipment. F. W. Fisher, Climate Control Div., Eaton Corp.

The demand for year round comfort systems in heavy duty trucks and off-highway equipment, dictated to some extent by OSHA requirements, is fast approaching that of the passenger car. This trend, as has been the history of automotive applications, is leading toward the O.E.M. adaptation of combination units wherein heater and evaporator are encased in a common assembly with air

directional capabilities for either operating mode. It offers the further potential of the reheat cycle as a temperature modulation means during air conditioning operation.

Heating principles are conventional in nature, utilizing engine coolant as the heat source. Cooling, while following basic automotive concepts, is more complex, particularly with respect to condenser placement and air filtration.

Performance sufficient to warrant customer satisfaction is an obvious requirement; durability, strength of materials and operating life of functional components, is an even more critical criterion. Continued development in this field is mandatory.

750401. Air Conditioning—The Integrated System. Ronald J. Brooks, Kysor of Byron Div., Inc., Kysor Industrial Corp.

The proper performance of an environmental-control system for commercial vehicles requires the proper matching of all components. The total cooling capacity is as much a function of the condenser, the compressor, the refrigerant lines, and the air distribution ducts as it is a function of the evaporator. With the increased usage of integral units, it is necessary to review these components and their effect on air-conditioning as an integrated system.

750402. An Evaluation of Transit Bus Air Conditioning Systems. Ronald D. Lemke, Thermo King Corp.

This paper consists of a study which was conducted to evaluate present transit bus air conditioning systems and to present some concepts which are desirable in future vehicles. Various cooling load requirements are examined and related to the present air conditioning systems. The requirements are further compared to the systems proposed for future vehicles. Particular attention is paid to the power consumption of present A/C systems and reducing the power consumption in future systems. Factors for improving the A/C system reliability are also evaluated.

750403. The Rovac Automotive Air Conditioning System. Thomas C. Edwards, Rovac Corp.

The ROVAC air conditioning system, a new system that employs air as the refrigerant, is a combination rotary compressor/expander unit. A prototype has been modeled, designed, fabricated, laboratory tested, and field tested in a full size four door 1973 Dodge Coronet. The description of the new system, the analysis, design and actual test results are reported here.

The objective of the engineering program was to demonstrate and prove the capability of the ROVAC system to effectively and efficiently air condition automobiles. The prototype system installed in the Dodge Coronet produces delivered cooling capacity on the order of one to one and a half tons per thousand rpm and has produced delivered coefficients of performance at relatively high humidity levels (150–180 grains water per pound of dry air) rivaling the best developed conventional vapor compression air conditioning systems.

While the present system reported herein has not reached the levels of performance predicted by detailed computer models, continued hardware improvement is facilitating actual performance very near the levels predicted to be practically achievable.

During actual in-car jury tests, the prototype ROVAC air conditioning system brings the average passenger compartment temperature from a thermally soaked condition of 107° F down to 72° F in less than two min with five passengers at an average road speed of 30 mph.

750404. Radial Ply Tires—How Different Are They in the Low Lateral Acceleration Regime. Dieter J. Schuring, Calspan Corp.; and R. Douglas Roland, AMF Inc.

The cornering and camber stiffnesses of about 160 passenger car tires were analyzed with the objective to assess the differences between radial ply, bias belted, and bias ply tires in their linear cornering properties. Radial ply tires could be clearly distinguished from bias belted and bias ply tires on the basis of their equivalent slip angles. Bias belted and bias ply tires, however, showed strong overlap in all their cornering data.

A vehicle cornering at low lateral accelerations does not exhibit distinctly different under/oversteer characteristics with the three generic tire types as long as they are not mixed. If they are mixed, large departures from the matched state may occur, particularly for radial ply/bias ply tire configurations. Large changes may also take place if tires are replaced by others of the same generic type but of different brands.

750405. The Effect of Belt Materials on Performance of Radial Passenger Tires. Marion G. Pottinger, B. F. Goodrich Co.

The effect on radial passenger tire performance of the four most common belt materials—fiberglass, Kevlar, rayon, and steel—is discussed in light of their contributions to tread band stiffness. The magnitude of the material effects on performance is compared to the magnitude of belt geometric design effects on performance. It is demonstrated that the belt material differences do have a significant effect on performance related directly to how the material differences affect tread band stiffness. It is also shown that other design effects can overwhelm differences due to material differences alone.

750406. Tire Induced Steering Pull. Richard W. Topping, B. F. Goodrich Co.

A theory of vehicle steering pull, created by asymmetrical tire cornering properties, is developed. It is validated with free control data obtained on the road.

The effects of tire lateral force and aligning torque asymmetries on a car's straight line stability are analyzed for both fixed and free control. Equations for front axle lateral force, steering system moment, and sideslip angle

are derived. They are based on tire properties and certain assumptions about the car's characteristics.

This theory is validated using data obtained in open road testing. The test techniques, as well as alternate ones, are described. In addition, the relationships between actual front axle force and axle conicity force, ply steer force, and lateral force offset are analyzed. It is found that front axle conicity force correlates very strongly with a more accurate theoretical prediction. The axle force predicted by tire conicity force is somewhat low.

750409. Cost and Energy Conservation with Powder Metallurgy. K. Imahashi, T. Suzuki and C. Tsumiki, Toyota Motor Co., Ltd. (Japan).

The application of the P/M and P/F methods in the production of automotive parts was investigated and compared to the conventional methods of casting and forging, with special attention paid to the areas of cost and energy conservation.

In relatively light parts weighing 200–500 grams, the use of P/M and P/F with pure iron powder resulted in a significant savings in both cost and energy consumption. In the heavier parts, however, this cost reduction was not realized because of the high cost for materials.

750410. The Economics of Conventional P/M Parts Production in the U.S. Leander F. Pease, III, Powder-Tech Associates, Inc.

Enough of the manufacturing details for powder metallurgy, (P/M) are presented, for the reader to be able to outline the steps required to make a P/M part. The production rates, hourly equipment costs, and raw material costs are provided, so that the cost of a P/M part can be estimated. Tooling costs may be estimated by comparison with a graded series of examples. Some simplified or rule of thumb methods are also provided for estimating the costs of parts with given strength requirements.

750411. Sulfuric Acid Emissions from an Oxidation-Catalyst Equipped Vehicle. Frederick A. Creswick, Ellsworth R. Blosser, David A. Trayser and John F. Foster, Battelle's Columbus Laboratories.

A 1973 Ford Torino with 1975 emission controls including monolithic noble metal catalysts was used to examine the effects of vehicle operating variables on sulfuric acid exhaust emissions. The vehicle was operated with and without the catalysts, at 60 mph and on an urban driving cycle (1975 FTP). H_2SO_4 and SO_2 were collected by a Goksøyr-Ross condenser coil with hydrogen peroxide bubblers in series sampling from a dilution tunnel. Filter samples were collected from the tunnel for total particulate mass, sulfate, and pH measurements. The size distribution of the exhaust sulfate particulates was investigated by cascade impactor.

At 60 mph, 36% of the fuel sulfur was emitted as H_2SO_4. On the 1975 FTP driving cycle, the figure was 10–24% depending on prior operating history, with small differences between cold and hot-start and between transient and stabilized phases of the cycle. Sulfur storage in the converter was minor. The emitted H_2SO_4 was composed primarily of droplets smaller than 0.3 μm. Without catalysts, emission of H_2SO_4 is $<1\%$ of the fuel sulfur.

750414. (SP-395) **The Effects of Exhaust Gas Recirculation and Residual Gas on Engine Emissions and Fuel Economy.** Yasuo Kaneko, Hiroyuki Kobayashi and Reijiro Komagome, Mitsubishi Motors Corporation.

Three exhaust emissions, hydrocarbons, carbon monoxide and oxides of nitrogen, from the automotive spark-ignition engines are presently subject to regulatory control. Of these harmful pollutants, NOx emissions are the hardest to control under current status of emission control technology. Accordingly, exhaust gas recirculation (EGR) has been receiving continued efforts as one of promising NOx control.

This paper reports the effects of EGR on the mechanism of NOx reduction and engine fuel economy, on the basis of research made in the following areas:

(1). NOx formation in a combustion vessel.

(2). Studies on EGR effects in a single-cylinder engine.

(3). Effects of EGR on NOx and HC emissions and fuel economy.

750415. (SP-395) **Trade-offs Between Engine Emission Control Variables, Fuel Economy, and Octane.** C. R. Morgan and S. S. Hetrick, Mobil Research and Development Corporation.

A single cylinder RDH spark ignition, gasoline engine operating at constant speed and load was used to study the effects of compression ratio, spark timing, exhaust gas recirculation (EGR) rate, and air/fuel (A/F) ratio on exhaust emissions, fuel economy and octane requirements. Analyses showed that fuel consumption decreased with increasing compression ratio at any given NO_x emissions level, so that minimum fuel consumption was obtained at the highest compression ratio studied when basic engine HC emissions were not a constraint. However, if both HC and NO_x emissions were constrained at constant low levels by optimal adjustments of EGR and spark timing, both the minimum fuel consumption and minimum octane number for trace knock were achieved at the lowest compression ratio studied. Furthermore, overall minimum fuel consumption at controlled HC and NO_x levels was obtained at the leanest A/F ratio (15.4) studied. Therefore, these data indicate that the historically accepted improvement in engine efficiency with increasing compression ratio may not always be achieved when HC and NO_x must be constrained due to emission requirements.

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750416. (SP-395) **An Approach to the Low Emission Engine with the Consideration of Fuel Economy.**

H. Kuroda, Y. Nakajima, Y. Hayashi and K. Sugihara, Nissan Motor Co., Ltd. (Japan).

A number of approaches to the development of low emissions engines have been reported in the literature. Many of these approaches, however, have reduced emissions by retarding ignition timing. This increases exhaust gas temperature for more complete HC oxidation in the exhaust system but results in a fuel economy penalty.

Previous studies by the authors indicated that NO_x can be effectively reduced with judicious use of EGR. While this may result in increased HC emissions, under some conditions it also can result in improved fuel economy.

The data reported in this paper demonstrate that the use of EGR is capable of reducing NO_x emissions and octane number requirements while improving fuel economy. Any resultant increase in HC emissions can be controlled with an efficient HC/CO oxidation catalyst.

750417. (SP-395) **NO_x Reduction Catalyst Development.** G. H. Meguerian and F. W. Rakowsky, Research and Development Dept., Amoco Oil Co.

As part of recent IIEC-2 activities, we have studied kinetics of ammonia formation to delineate engine conditions for best net NO_x efficiency and to expand the choice of emission control systems. These studies have been carried out in the laboratory with exhaust gases generated by a pulse flame generator and rhodium containing catalysts. Catalyst selectivity, NH_3/N_2 was found to vary linearly with the CO/O_2 ratio in the exhaust gas and with the reciprocal of the space velocity. The effects of temperature and input NO_x levels are more complex: Selectivity shows a maximum in the range of 750–1300°F and increases gradually as the NO_x level is decreased from 800 to 100 ppm. Based on these results a mechanism is proposed for ammonia formation and a triple-catalyst system is suggested for increasing net NO_x efficiency.

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750419. (SP-395) **Methanol-Gasoline Blends Performance in Laboratory Tests and in Vehicles.** A. W. Crowley and J. P. Kuebrich, Atlantic Richfield Company; M. A. Roberts, Ford Motor Company; W. J. Koehl and W. L. Wascher, Mobil Research and Development Corp.; and W. T. Wotring, Standard Oil Company (Ohio).

Blends of up to 20% methanol in gasoline were evaluated in both engine dynamometer and controlled vehicle tests, and in a 50,000 mile road test. Performance comparisons between methanol blends and base gasolines were made in vehicle driveability and vapor lock tendency, engine deposits and wear, fuel economy, exhaust emissions, compatibility with fuel system materials, and phase stability of the blends. Vapor lock tests in six 1974 cars strongly suggested that the vapor lock tendency of methanol blends is greater than would be predicted for gasolines having the same volatility characteristics. Cold start and warm-up driveability of two 1974 cars at 70°F depreciated as methanol concentration increased in base fuels of three volatility levels. These driveability data were found to correlate well, at a given methanol concentration, with fuel volatility characteristics described by means of a new fuel vaporization pressure technique. Engine deposits, rusting, wear and crankcase oil performance were not significantly affected by methanol in gasoline when evaluated in four laboratory engine tests and in the four-car, 50,000 mile road test. Fuel consumption was found generally to increase with increasing methanol concentration, while exhaust emissions from both vehicles and stationary engines varied as expected from the stoichiometric air/fuel ratio of the blends. With the possible exception of copper and brass, screening tests with methanol blends indicated no serious potential compatibility problems with the fuel system metals tested or with Buna N or Neoprene rubbers. Methanol solubility in gasoline was shown to be increased by co-solvent alcohols. These also increased the stability of blends to phase separation by added water, but still phase separation occurred with as little as O.1 or 0.2% of water.

750420. (SP-395) **Combustion and Emission Characteristics of Methanol.** J. A. Harrington and R. M. Pilot, Scientific Research Staff, Ford Motor Company.

A single cylinder engine was used to study the combustion and emission characteristics of methanol and indolene clear fuel. Measurements on ignition delays, combustion intervals, power and exhaust emissions were made over a range of speeds, loads and air-fuel mixture ratios. The results were used to determine the difference in relative power, efficiency and emissions between the two fuels.

Relative to Indolene, methanol exhibits faster overall burning rates, (shorter ignition delay periods and combustion intervals). At the same engine air flows and equivalence ratios, methanol produces more power than Indolene. Fuel consumption with methanol is higher but the energy consumption rate is lower. NO emissions with methanol are generally lower but, depending on equivalence ratio, CO and HC emissions are less than, equal to or greater than those with Indolene fuel.

Discussion: J. K. Appeldoorn, Products Research Div., Exxon Research and Engineering Co.

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750421. Use of Aluminum in Automobiles—Effect on the Energy Dilemma. C. N. Cochran, Aluminum Co. of America; F. R. Abele and T. Eckert, Howmet Corp., G. A. Alison, The Aluminum Assn., P. E. Anderson, Martin Marietta Aluminum, Inc., L. Campbell, Southwire Co.; and F. Testin, Reynolds Metals Co.

For a variety of reasons, cars have been getting heavier. A standard-size Chevrolet, for example, weighed about 3,700 lb in 1963 and 4,600 lb in 1973. Since there is a direct

correlation between vehicle weight and gas mileage (EPA figures show an average of 24 mpg for a 2,000 lb car versus 11 mpg for a 4,000 lb car), weight reduction becomes an attractive means of increasing gasoline mileage. Also it can often be accomplished without compromising comfort and safety features.

To help cope with the energy dilemma, more efficient use of gasoline in cars is needed. Aluminum, with a proven track record in weight reduction in cars and all other transportation vehicles, offers an ideal solution to auto weight problems.

Immediate primary weight saving of 1.5 lb can be obtained by substituting a single pound of aluminum in place of auto parts made of traditional materials. This saving also permits use of lighter structural supports —again adding to the weight saving.

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750422. Anatomical and Functional Measurements, Criteria for Human Adaptation within a Driver's Control Area. A. Coblentz and G. Ignazi, Laboratoire D'anthropologie Et D'ecologie Humaine (France).

In the research and development of a driver's control area, one of the analytical procedures consists of studying and considering data at distribution extremes for each anthropometric measurement. Among the anthropometric measurements, one of the foremost is undoubtedly stature, which appears to be evidential of the differentiation in the study of a human group.

750424. Mass Distribution Properties of the Male Cadaver. Herbert M. Reynolds, Highway Safety Research Institute; Charles E. Clauser, Wright-Patterson Air Force Base; John McConville, Webb Associates; Richard Chandler and J. W. Young, Civil Aeromedical Institute, FAA.

Mass distribution properties of the human body and its fourteen primary segments were measured in three dimensions using six male cadavers. Data collected include anthropometry, mass, center of mass, and the principal moments of inertia. The principal moments of inertia were computed using a 3×3 matrix of values derived from simple pendulum measurements about six nonparallel axes.

Anatomical segmentation procedures used are emphasized and compared with those in previous investigations. In addition, comparisons of the measured data with extant data in the literature on the whole body and its segments are presented and discussed.

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750429. Anthropometric Basis of the GM ATD 502 Crash Test Dummy. Robert P. Hubbard, Research Labs., General Motors Corp.

Human anthropometry was used as input to the design of the GM ATD 502 crash test dummy. The spinal column of an average adult male was located for an erect seated position leading to guidelines for placement of dummy components and sectioning of the dummy into segments. The weight and weight distribution of these dummy segments were defined based on anthropometric data. These results provide some assurance that the size, relative location, and weight distribution of dummy structures are representative of human characteristics.

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750430. Dynamic Anthropometry and Design of a Vehicle Driver's Control Area. A. Coblentz and G. Ignazi, Laboratoire D'anthropologie Et D'ecologie Humaine (France).

To make it possible for a driver to get the best advantage of it, a vehicle driver's control area must be so designed as to comply with morphological and biomechanical requirements. If such requirements are met, the best compromise may be found between the need for comfort, safety and optimum efficiency of the Man/Machine complex.

Problems encountered in the achievement of a more or less elaborate driver's control area are of different kinds:

1. Dimensional analysis of the space used by the driver and relative motions of anatomical elements. In other words, it is essential to further investigate the overall or segmentary room within standard reference attitudes, then attitudes imposed by the proper location of controls. Afterwards, it is necessary to study the changes in this room during the motions required to perform automotive driving phases. This task can either be the handling of a control or shifting from one control to another.

2. Performance variability analysis in relation to control position within the defined activity space.

Actually, we easily conceive that such a method of analysis can only bring valuable knowledge if it takes into account a fundamental factor too often neglected as regards material and equipment design, that is the development of morphological features of using population.

750431. (SP-393) **What is a Microprocessor?** Joseph BouFaissal, Natl. Semiconductor Corp.

A microprocessor is a device capable of automatically carrying out a sequence of operations on data expressed in discrete (digital) or continuous (analog) form. The purpose of a computer or a microprocessor is to solve a problem or class of problems; the problem may be one of control, analysis, or a combination of the two. Without a doubt, any problem a computer can solve, a man could solve. The advantage is one of time. On a series of complex analytical problems, a mathematician could dedicate his entire life to do what a computer could do in mere seconds; similarly, no human could continuously analyze new stimuli and generate responses in the microsecond intervals required by modern electronics and electromechanical hardware.

As much as we refer to computers for microprocessors as one entity, we will try to spell out capability, structure, and economic differences.

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750432. (SP-393) **Application of Microprocessors to the Automobile.** T. O. Jones, General Motors Technical Center; T. R. Schlax and R. L. Colling, General Motors Corp.

This paper describes microprocessor technology as it may be applied to the automobiles of the future.

The microprocessor requirements described in this paper were generated as a result of the evaluation of the Alpha IV vehicle system which utilizes a solid-state, digital 4-bit, microprocessor to perform several vehicle control and display functions. The development of the Alpha IV system encompassed not only the interface circuit design and microprocessor programming, but also, the derivation of the digital algorithms and control laws for the functions which have traditionally been performed in an analog fashion.

The control functions performed include: Cruise Control, Four-Wheel-Lock Control, Traction Control, Speed Warning, Speed Limiting, Ignition Spark Advance and Dwell, Automatic Door Locks, and Anti-Theft System. The display functions include: Speedometer (both analog and digital), Odometer, Trip Odometer, Tachometer, Clock, and Elapsed Time.

750433. (SP-393) **Engine Control by an On-Board Computer.** David F. Moyer and Suresh M. Mangrulkar, Ford Motor Company.

A spark ignited internal combustion engine with computer controlled spark and exhaust gas recirculation has been operated over the CVS test cycle. At the 1975 emission level, a 10-20% improvement in fuel economy on the test vehicle over the initial production 1975 California vehicle was measured. Comparable driveability, octane, emission levels, and performance were obtained. The initial calibration for the control of spark and EGR was developed from engine dynamometer testing; computer simulations allowed for calibration development prior to vehicle implementation. Cost effectiveness questions have not been resolved.

750434. (SP-393) **Design Considerations For an On-Board Computer System.** R. S. Oswald, N. L. Laurance and S. S. Devlin, Ford Motor Co.

A programmable digital logic system has been developed for vehicle powertrain control. The system is configured around a custom microcomputer, and has been demonstrated in the control of ignition timing and exhaust gas recirculation rate in a vehicle installation. The specific design resulted from considerations of performance, reliability, serviceability, flexibility, and cost. This work at Ford has made further contributions to establishing the feasibility of an On-Board Computer system for vehicle application, but direct cost effectiveness is not yet established, and many problems remain unresolved.

750436. (SP-393) **Electronic Fault Monitoring and Diagnosis in Air Bag Systems.** Morton S. Balban, Safety Systems Div., Eaton Corp.

A very high level of confidence must be maintained at all times that the air bag passive restraint system and each of its components are in proper operating condition to function as required when called upon to do so. Electronic circuitry which continuously performs non-destructive testing is used to monitor the system components, connectors, and wiring integrity. This fail-safe circuitry, which incorporates self-check features, causes a fault indicator to become illuminated should a fault exist in any part of the air bag system. A fault analyzer, which pinpoints the exact location and nature of a fault, is available for system servicing and/or system final assembly verification.

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750437. **Electronic Air Core Wide Angle Tachometer.** C. S. Cardani, C. F. Raiss and R. A. Grimm, AC Spark Plug Div., General Motors Corp.

The wide angle air core tachometer has been developed as an alternative to the D'Arsonval type tachometer. Differences between the air core mechanism and D'Arsonval meter movement have forced the design of new drive electronic circuitry which would transform a linear output voltage to two bidirectional output wave forms. Combination of the new circuit and existing gage assembly is built into a tachometer assembly and is being produced in high volume utilizing automated assembly and computerized laser test and adjust equipment. Expansion of the concept will allow application to pressure and temperature gages, pyrometers, speedometers, etc.

750438. (SP-393) **Fundamentals of Automotive Electrical Distribution.** Jerry A. Foreman, Ford Motor Co.

The substantial growth of new electrical and electronic components on today's passenger vehicles has required the development of complex distribution systems to service these components. Design of a cost effective, highly reliable electrical distribution system for the modern vehicle has become an exciting challenge to the responsible design engineering activities. An equal challenge is presented to the electronic engineer working in automotive electronics since he must now pay careful attention to the distribution system that will be servicing his components.

This paper provides a point of reference to the electronic designer by examining key factors in the development of an electrical distribution system for a modern automobile. In this discussion, primary emphasis is devoted to the design of a fault protected distribution network that is compatible with the state-of-the-art in automotive component design and assembly processes.

750439. **Control of the Subway Environment.** Arthur G. Bendelius, Parsons, Brinckerhoff, Quade and Douglas, Inc.

This paper addresses the overall subject of environmental control in the subway portions of rapid transit systems. A review of the history of subway environmental control

along with an updated report on the recent research work conducted under the auspices of the Transit Development Corporation, the U.S. Dept. of Transportation and the subway operating properties is included. To conclude the paper, a presentation is made of the analytical work presently being pursued for the system under design in Atlanta.

750440. Mass Transportation Vehicles and People Movers. Richard A. Heck, Sundberg-Ferar, Inc.

The purpose of this paper is to give an overview of developments in mass transportation vehicle and people mover design and to illustrate the constraints facing the industrial designer.

To discuss specific transportation projects which Sundberg-Ferar has been directly involved in, such as the San Francisco BART Car; the Washington, D.C. Metro; the New York City Transit Authority R-44 Subway Car; the Morgantown and Dashaveyor people movers. Also, vehicle design for both exterior and interior components with commentary on design criteria and final results.

750441. Highlights of UMTA's Rail Program. Joseph S. Silien, U.S. Dept. of Transportation.

This paper highlights the role rail research programs of the Urban Mass Transportation Administration (UMTA). Included are descriptions of several recently developed commuter transit cars—the state-of-the-art Car, The Advanced Concept Train and dual-powered, gas turbine/electric cars. Also discussed are efforts by UMTA in developing test facilities for urban rail vehicles and in furthering research in tunneling technology and noise abatement.

750442. BART Progress Report. W. P. Quintin, Jr. and T. S. Eanes, Bechtel, Inc.

The need for some kind of modern transit system as an alternative to the automobile in the San Francisco Bay Area had its genesis over a quarter century ago, at a time when the established transit systems in the area were suffering decreasing patronage and freeways were gaining popularity in California. This is a report on the actions which developed from early recognition of that need. The report describes the concept of BART and the major experiences translating that concept to its present operation in revenue service. At the conclusion, the report gives an account of BART's patronage and its trend as an indicator of its acceptance as a People Moving System.

750443. Mass Transportation: A National Commitment. T. A. Lancaster and D. L. Hearn, Rohr Industries, Inc.

The United States is fast approaching a crisis in urban mobility. The major streets and freeways that provide for the movement of people and goods throughout the major urban areas are becoming so congested that urban life style is deteriorating. This congestion combined with our fuel crisis and clean air requirements are mandating a need for concerted effort to improve urban public transportation. This paper emphasizes the need for a national commitment to public transportation and the need for legislative action to provide the stable long-term funding. It is estimated that a $77 billion commitment could provide the systems and rolling stock for public transit to attract upwards of 38 billion trips by 1990. The three basic modes of ground transportation—rail transit, bus, and automated personal rapid transit—are discussed and their relative role and funding needs advanced. On a national basis, when weighed against other national commitments such as our interstate highway system and space exploration, the $77 billion funding commitment estimated between now and 1990 is bold but achievable.

750444. Urban Rapid Rail Vehicle and Systems Program Progress. David E. Hervey, Boeing Vertol Co.

This paper describes the content, objectives, and status of the U.S. Dept. of Transportation's Urban Mass Transportation Administration's Urban Rapid Rail Vehicle and Systems Program (URRVS). The URRVS Program includes the following separate but interrelated programs:

1. BART Monitor.
2. State-of-the-Art Cars (SOAC).
3. Advanced Concept Train (ACT-1).
4. Advanced Subsystems Development Program (ASDP).
5. Advanced Concept Train Future Planning (ACT-3).

750445. PRT Impact on Transportation. W. J. Holt and L. Samusson, Rohr/Monocab, Inc.

The increasing congestion of urban areas requires multimodal transportation solutions. Personal Rapid Transit (PRT) is discussed as one of the supporting modes for regional systems as a feeder to high-speed corridors and for circulation and distribution missions.

PRT may begin as small loop or linear systems and expand to complex network grids in planned phases. For equal dollars spent, increased ridership and route coverage is possible with PRT systems versus line-haul corridor systems. All modes must complement each other.

750446. Urban Deployment of an Aerial Guideway People Mover in the Detroit CBD. Robert J. Dietz and Murthy V. A. Bondada, Gannett Fleming Corddry and Carpenter, Inc.

This paper presents findings of the functional and engineering feasibility studies for an aerial guideway people mover system (PMS) within the Detroit Central Business District (CBD). Emphasis is placed upon the process of developing alternative alignments and their evaluation. A detailed discussion is included regarding the problems of constructing an aerial guideway within an existing urban center and how the environmental requirements are met in achieving a plan commanding broad-based community support.

750447. The Effect of Lubricant Additives on the Dura-

bility of Platinum Oxidising Catalysts. W. Fitzgerald, Esso Chemical Ltd. (United Kingdom); and J. V. D. Wilson, Edwin Cooper & Co. Ltd. (United Kingdom).

The presence of a metal such as calcium or zinc in a lubricant appears to inhibit the poisoning effect of phosphorus on platinum oxidising catalysts. This is a general conclusion from rig, engine and vehicle tests on lubricants with different additive components. Among the test results reported a lubricant blend with 2.5% by weight ZDDP (O 22% wt Zn) and another blend with 1.25% wt ZDDP plus enough phosphorus containing ashless antioxidant to double the phosphorus content of the lubricant both gave satisfactory performance in terms of catalyst degradation.

750448. Field Service Compatibility of Ashless and Fully Compounded Engine Oils with Two Bead-Type Oxidation Catalysts. A. T. Meyers, Chevron Research Co.

Eight catalytically equipped vehicles were used to compare the effects of an ashless, nonphosphorus lubricant and a conventional SE lubricant on the deterioration of two different types of bead catalyst operating in field service. Composite CO emissions (measured by the 1975 Federal Test Procedure) approximately doubled during the 25,000-mile test with both oils relative to the fresh catalyst. No significant increase in composite HC emissions was shown. There were no significant differences between the two oils with respect to either HC or CO emissions at the end of the test. Analysis of the aged catalyst showed average phosphorus contamination of 0.07 wt % with the conventional oil compared to 0.01 wt % with the ashless oil. The higher level of phosphorus contamination with the conventional oil was not accompanied by an increase in catalyst deterioration relative to the ashless oil.

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750449. The Role of Lubricant Additives in Controlling Abnormal Combustion (ORI). P. A. Barber, T. F. Lonstrup and N. Tunkel, PARAMINS Technology Div.

This paper reviews the effects of several lubricant related variables on abnormal combustion. The effects of basestocks, sulfated ash level, metal detergent type, and viscosity improver are discussed. The data indicate that improved customer satisfaction can be achieved by design of lubricant type and additive components. Ashless or low sulfated ash oils, and those formulated with hydrocarbon viscosity improvers are shown to contribute less toward ORI and other types of abnormal combustion. In addition, the choice of metal detergent is found to be important. The range of improvement can be as much as 4 octane units. An attempt is made to relate viscosity improver structure to stability and combustion chamber deposit forming tendency. Laboratory, engine, and field test data are presented.

750451. (SP-395) **Establishment of ORI Characteristics as a Function of Selected Fuels and Engine Families.** H. T. Niles, R. J. McConnell and M. A. Roberts, Scientific Research Staff, Ford Motor Co.; and R. Saillant, Scientific Research Staff Ford Motor Company.

Octane requirements of 55 cars, representing five Ford engine families, were determined every 2000 miles during a deposit accumulation schedule consisting of city, suburban and highway operations. Five cars from each engine family were operated on certification durability fuel to establish the ORI variation within and between families. Additional cars and fuels were used to investigate the effects of lead content, a detergent additive, and higher boiling fuel components on ORI.

The data obtained show that among engine families there were characteristic differences in ORI and that the initial ORI build up occurred more rapidly when the investigated detergent additive was used. The fuel with reduced tail-end volatility was found to increase ORI. ORI with leaded versus unleaded fuels was found to be greater with unleaded fuels but with wide variation between the engine families studied.

750454. Engineering the Third Generation Econoline. T. J. Walsh, Ford Motor Company.

This paper discusses the techniques employed in the development of the 1975 Ford Econoline Van, Club Wagon, and Cutaway vehicles.

The presentation highlights the key elements of engineering a new family of light trucks. A brief review of historical van and bus market trends and their role in determining new vehicle design objectives is included. Specific engineering subjects discussed are:

1. Body-on-frame structural design applied to van/bus/cutaway vehicles.
2. Development of an energy absorbing frame for these forward control trucks.
3. Engineering techniques applied to the resolution of vehicle shake problems.
4. Modifications to front and rear suspension for optimum ride, handling and tire wear.
5. Development of integrated climate control systems for van/bus vehicles.
6. The engineering of derivatives for body builder recreation vehicle markets.

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750455. Manufacturing the Third Generation Econoline. C. L. Knighton, Automotive Assembly Div., Ford Motor Co.

This paper presents highlights of assembly operations for the new 1975 model Ford Econoline III. All major assembly operations are covered. However, particular emphasis is placed on the automation used in body assembly. Econoline body and paint operations are performed at Ford's Ohio Truck Plant. Painted bodies are transported via special vans to the Lorain Assembly Plant for trim, frame and final assembly operations.

750456. Roughness in Steel-Belted Radial Tires—Measurement and Analysis. K. D. Marshall and N. W. St. John, B. F. Goodrich Co.

The roughness performance of sixteen (16) steel-belted radial tires has been studied using high speed uniformity, subjective evaluations, and instrumented vehicle techniques. An analysis of the results indicates that tractive force variation was the principle tire non-uniformity causing roughness in the subject test vehicle, and most probably in a large variety of other 1973 vehicles. This result is due primarily to the fact that the first tractive mode resonance of radial tires (28 Hz) interacts strongly with the principle transfer function resonances for 1973 vehicles (20-40 Hz). This work has also shown that ride jury ratings correlate well with vehicle instrumentation.

750457. Tire Testing for Rolling Resistance and Fuel Economy. D. A. Glemming and P. A. Bowers, Goodyear Tire & Rubber Co.

The rolling resistance of passenger tires and the fundamental factors influencing results from laboratory and road testing are discussed. Test methodologies for laboratory testing, rolling resistance trailer, vehicle coastdown, and vehicle fuel consumption tests are discussed.

The major emphasis is on the direct comparison of the bias belted tire with the steel belted radial tire to demonstrate the effect of tire construction, test method, and test parameters on tire performance. Observations are made regarding test methods and the significance of certain data.

750458. Bead Contact Pressure Measurements at the Tire-Rim Interface. J. D. Walter, Firestone Tire & Rubber Co.; and R. K. Kiminecz, Systems Research Labs.

A method has been developed for measuring the normal contact pressure distribution at the interface between a tire and a rim using a miniature magnetostrictive transducer as the load sensor. The transducer itself is a 0.050 in. diameter nickel ferrite toroidal core wrapped with primary (excitation) and secondary (sense) windings. As the core is stressed, the magnetostrictive phenomenon causes an increase in the magnetic flux and a corresponding change in the induced output voltage across the sense windings. This voltage change is signal conditioned to yield a dc voltage output as a function of core stress which is proportional to the bead contact pressure.

Bead contact pressures were mapped at the interface between various radial tires and rims under static and dynamic loading conditions. Static pressure distributions obtained for the inflated but otherwise unloaded condition provide a measure of the conformability of the tire to the rim. Dynamic pressure distributions show stress patterns developed under straight-ahead rolling and cornering conditions.

With the aid of such bead contact pressure measurements, stress analysis studies of tires and wheels can now be conducted on a more rational basis than done in the past because the exact nature of the load distribution at the tire-rim interface is known for various tire loading conditions.

750459. Evaluation of Tire Abrasion in Terms of Driving Severity. A. Chiesa and G. Ghilardi, Industrie Pirelli S.p.A. (Italy).

The purpose of the study is to establish which test conditions best reproduce the relative ratios of tire wear rate which exist between the different types of tires to be found in the field. Three fundamental parameters are defined which characterize the type of wear: specific wear rate, profile shape, and ratio of wear rates between the front and rear axles. The research is developed in three phases: an examination of the various modes of wear present in actual usage, abrasion tests carried out with great precision and at various levels of acceleration severity, and the correlation between the market wear spectra and the test data.

The paper concludes that the ratio of wear rates existing between any two types of tire is not generally constant, but it changes in function of the driving severity, thus explaining the disagreement sometimes found when comparing tests made at different centres. The appendix contains a survey made about the problem of the result consistency, including checks in the preparation of tests, definition and execution of the tests and the validity of the results.

750461. The Mechanics of Rollover as the Result of Curb Impact. Ian S. Jones, Calspan Corp.

This paper analyses the mechanics of overturning which occurs as the result of a vehicle colliding with a curb or similar obstacle. Because the duration of impact is short, the forces involved may be treated as impulsive forces and a graphical method may be used to determine the terminal velocities after the impact. The mathematical analysis is supported by results obtained from a film of an actual track test in which rollover was induced by sliding a car sideways into a curb. The motion of the vehicle after impact with the curb was also analysed in this film. During airborne motion, the car may be considered as a simple projectile and any aerodynamic effects neglected.

750462. Weldbond and its Performance in Aluminum Automotive Body Sheet. J. D. Minford, F. R. Hoch and E. M. Vader, Aluminum Company of America.

In weldbonding, a joint is produced by (a) spotwelding through an uncured adhesive bondline or (b) flowing adhesive by capillary action into the bond area after spotwelding. Weldbonding can offer higher joint strength, reduced joint weight, improved fatigue life and, in some aircraft-oriented investigations, showed reduced manufacturing costs.

Although weldbonding has had repeated use in the Russian aircraft industry, it has not been widely employed in American manufacturing to date. The most intensive

efforts to develop the process have resulted from contracts sponsored by the U.S. Air Force. The only aluminum alloys used in these investigations were the high strength aircraft alloys and the emphasis was to develop the highest strength weldbond joints with economics a secondary consideration. These studies usually included the use of special surface treatments on the aluminum, special adhesives, and carefully controlled curing conditions. No information has been available in the literature on weldbonding of the aluminum alloys currently suggested as automotive body sheet nor the adhesives and curing procedures commonly used in automotive, truck and trailer manufacturing processes. This investigation was undertaken to develop some of the fundamental information necessary to adapt the weldbond process to those industries using materials and test procedures described in an earlier paper on adhesive bonding of aluminum auto body sheet alloys.

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750463. Tensile-Shear and Fatigue Properties of Resistance and MIG Spot Welds of Some Aluminum Auto Body Sheet Alloys. N. L. Person, Kaiser Aluminum & Chemical Corp.

Tensile-shear static and fatigue tests were conducted on MIG (GMA) spot welds in various combinations of 2036-T4 and 5086-H32 sheet with thicknesses ranging from 0.035 in to 0.125 in. Both single-spot and double-spot coupons were welded for each alloy combination. Although the average weld diameter at interface did not vary much among the various alloy and thickness combinations, the static and fatigue strengths increased substantially as the overall thickness of the lap joints increased. Filler alloys 4043 and 5356 produced similar fatigue strengths. On a pound/spot basis, the single-spot coupons had slightly higher fatigue strengths than the double-spot ones.

Tests were also conducted on resistance spot welds in combinations of 2036-T4, 5056-O, 5056-H111, and 5052-H32 sheet having thicknesses of 0.035 in and 0.050 in. With fatigue load expressed in pounds, the 0.035 in thick sheet welds had very similar fatigue curves. The curve for the higher strength 5052 welds (0.050 in thick sheet) was substantially higher than for the thinner sheet. For the same sheet thickness and weld diameter, resistance spot welds gave slightly higher static strength than MIG welds. For 0.035 in thick 2036, the MIG spot welds had fatigue strengths (based on percent of static strength) similar to those of resistance welds.

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750464. Performance of Aluminum in Bimetallic Assemblies. W. King, G. Sowinski and E. T. Englehart, Alcoa Laboratories.

This paper discusses the corrosion performance of aluminum alloys for automotive applications when employed in bimetal assemblies. The basic electromechanical principles of galvanic corrosion are reviewed, and a series of accelerated corrosion tests performed on dissimilar metal assemblies is described. The relevant factors most severely affecting the degree of corrosion are: type of dissimilar metal, anode-to-cathode area relationship, and type of environment. Approaches to combating galvanic corrosion of aluminum include use of compatible parts, paint coatings, sealants, tapes, and gaskets.

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750466. Improved Asbestos Matrices for Alkaline Fuel Cells. W. B. Crandall and Y. Harada, IIT Research Institute.

Hydrogen-oxygen fuel cells have a good potential for use either alone or with other "batteries" to form a hybrid power supply for certain automotive uses. One of the drawbacks in the use of the hydrogen-oxygen fuel cell is corrosive effect that the potassium hydroxide electrolyte has upon the interior of the cell, particularly the asbestos matrix separation.

The purpose of this study was to determine how to increase the present operating temperature of this cell ($<100°C$) by increasing the corrosion resistance of matrix material. Two methods of reducing the potassium hydroxide-asbestos reaction were found and are described in this paper.

750468. A Computer Program for Calculating Properties of Equilibrium Combustion Products with Some Applications to I.C. Engines. Cherian Olikara and Gary L. Borman, University of Wisconsin.

A computer program which rapidly calculates the equilibrium mole fractions and the partial derivatives of the mole fractions with respect to temperature, pressure and equivalence ratio for the products of combustion of any hydrocarbon fuel and air is described. A subroutine is also given which calculates the gas constant, enthalpy, internal energy and the partial derivatives of these with respect to temperature, pressure and equivalence ratio. Some examples of the uses of the programs are also given.

750469. Effect of Alcohols as Supplemental Fuel for Turbocharged Diesel Engines. K. D. Barnes, D. B. Kittelson and T. E. Murphy, University of Minnesota.

Alcohols are examined as supplemental carbureted fuels for highspeed turbocharged diesels as typified by the White Motor/Waukes ha F310 DBLT (6 cylinder, 310 cu. in.). Most of the work was with methanol; ethanol and isopropanol were compared at a few points. Fumigation (dual-fueling) with alcohol significantly reduced smoke and intake manifold temperature. These effects were largest at high load. Efficiency and HC emissions were essentially unchanged. Cylinder pressures and rise rates were examined for possible adverse effects on engine structure. The range of speed and load favorable to alcohol dual-fueling are such that, should alcohols become economically competitive as fuels, a practical duel-fuel system could be applied to existing diesel engines.

750470. A Quiet, Efficient Controller for Electric Vehicles. Dan Armstrong and Michael Pocobello, Triad Services, Inc.

This paper presents an alternative to conventional resistive, SCR or battery switching controllers for wound-field D.C. motors. A system has been built and tested which keeps battery current (as selected by the driver) constant throughout any maneuver without the problems associated with switching controllers. A system description is included along with test results. Comparisons are made with battery scanning, SCR, and other control types which show this system of combined field control, voltage switching and armature current control to be more efficient.

750471. Thermal/Voltage Response Characteristics of Automotive Nonantimonial Lead-Acid Batteries. Charles E. Wright and Vincent M. Halsall, Globe Battery Div., Globe-Union Inc.

The critical temperature/voltage relationship for initiation of thermal runaway is characterized for standard antimonial, low antimonial, and nonantimonial automotive lead-acid batteries. Current acceptance under overcharge conditions over the full range of normal operating temperatures and applied voltages is also reported. These data quantify the merits of removing antimony from lead-acid batteries.

750472. Evaluation of Two Convex Mirror Systems by Government Drivers. Charles H. Kaehn, Dept. of Transportation.

A nationwide field study of two types of convex mirror systems was made by the National Highway Traffic Safety Administration (NHTSA) with the cooperation of the General Services Administration (GSA) for a 10-month period starting in January 1974. One convex mirror system, called the Type I system, consisted of a non-adjustable convex mirror on the right fender, the original outside mirror on the driver's door, and a larger inside mirror. The Type II mirror system consisted of an adjustable convex mirror mounted on each fender and the original inside rearview mirror.

A total of 515 Federal employees evaluated these two convex mirror systems at six major test locations to provide 627 questionnaires. An analysis of the questionnaires shows that drivers preferred the Type II convex mirror system over the Type I. From comments received, it seems that the drivers objected mostly to the non-adjustable feature and restricted field of view of the Type I system rather than to the fact that it was only a one-convex mirror system as compared to a two-convex mirror system. However, neither convex mirror system was rated as highly as the periscope system was evaluated in a previous field test of 50 periscope equipped GSA automobiles. This suggests that drivers would prefer unit magnification mirror systems with larger rearward fields of view over convex mirror systems with roughly the same view; nevertheless, drivers also prefer the convex mirror systems tested over conventional mirror systems because the convex mirrors provide greater rearward visibility.

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750473. Preparation and Operation of Diesel Engines in Construction and Industrial Machinery for Operation in Cold Climates. W. G. Bugelski, Cummins Engine Co., Inc.

The contents of this publication is the summary of many papers and varying subjects pertaining to cold weather preparation of diesel engines for operation in cold weather and arctic climates. The approval by the U.S. Government on the construction of the Alaska Pipe Line and opening of the North Slope oil fields was instrumental in furnishing the initiative to publish existing documentation in one paper.

It has been difficult to avoid controversial areas and still present what we hope represents the areas which require attention when operating a diesel engine in cold and/or arctic climates and some of the varying specialized equipment our experience indicates can be helpful.

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750474. Investigation into the Degree of Application of the Frequency Parameter at Part Throttle Condition in Gasoline Engines. H. Sezgen, Middle East Technical University (Turkey).

In the present investigation, the main aim was to apply the frequency parameter for viscous flow air meters to the measurement of air consumption of gasoline engines at full- and part-throttle conditions. In the previous investigation, it was verified only for a single-cylinder, 4-stroke engine without a carburetor.

Experiments have shown that at higher engine speeds, the linear relationship between the rate of flow and the pressure difference deviates. Thus, the frequency parameter obtained at deviation speeds for each viscous flow meter can be used as a criterion for the dependable working range.

As a result, an exponential relationship has been found between the frequency parameter and the plate distance of the viscous flow air mater. According to this relationship, it is clear that the dependable working range of the viscous flow meters increases when applied to the engine running in part-throttle condition.

750476. Shielded Arc Welding of Some Aluminum Sheet Alloys. E. G. Eichhorn and I. B. Robinson, Kaiser Aluminum and Chemical Corp.

This paper will concentrate on one area of aluminum alloy joining shielded arc welding. This will often be the process of choice for fabricating structural components from multiple sub-parts, attaching some permanent brackets and reinforcements, for closing designed seams in drawn parts where severe local forming requirements exceed material capabilities, and for in-process repair of sheet tears and splits.

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750477. A Model of Quench Layer Entrainment During Blowdown and Exhaust of the Cylinder of an Internal Combustion Engine. R. Edwin Hicks, Ronald F. Probstein and James C. Keck, Massachusetts Institute of Technology.

An aerodynamic model of the entrainment of the head wall quench layer during blowdown and exhaust of an internal combustion engine has been developed. The model may be used to calculate the time resolved concentration and mass flowrate of hydrocarbons (HC) in the exhaust, from a knowledge of engine geometry and operating conditions. It predicts that the area A_s from which HC are swept will be proportional to the cube root of the ratio of the quench layer thickness δ_q to the thickness of the viscous boundary layer δ_v. Since the mass of HC emitted is proportional to the product of the HC density ρ_{HC}, the area A_s and the thickness δ_q, the HC emissions will be proportional to the product $\rho_{HC}\delta_q^{4/3}$ and this is the most important factor determining the emissions.

The model also predicts that the time dependence of the HC mass flowrate will depend relatively strongly on the pressure ratio p_4/p_e across the exhaust valve when it opens: in an unthrottled engine virtually all the head wall HC exit during blowdown; in a heavily throttled engine the HC are emitted more or less uniformly during the exhaust stroke.

It is expected that the model will be useful both for interpreting experimental measurements of HC emissions and for predicting HC emissions from practical engines. Comparisons of the results obtained to date with the available experimental data shows good agreement.

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750500. NASA General Aviation Research Overview —1975. Roger L. Winblade and Judy A. Westfall, NASA Headquarters.

An overview of the 1975 NASA Research and Technology efforts directly focused on general aviation is presented. Current status and accomplishments during the past year are described. An updated bibliography of technical reports generated by the NASA program, including seven recently declassified reports on airplane noise reduction, is included as an Appendix to this report.

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750502. Summary of Systems Design Studies of Turbofan Powered Light Aircraft. Mark H. Waters, Ames Research Center, NASA.

The NASA sponsored studies of the potential of the turbofan engine for light aircraft have approached the total aircraft design and mission rather than the engine cycle and design alone. In addition, the commonality of military trainer and civil requirements have been addressed. It has been demonstrated that the proper choice of turbofan engines coupled with advanced wing and flap design will result in either a superior or comparable aircraft design for all classes of light aircraft. Improved noise and emission characteristics can be expected with comparable fuel consumption. Costs are a question mark, but high volume production techniques could result in marked reductions in turbofan engine costs.

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750504. NASA Aircraft Operations and Safety Research of Potential Application to General Aviation. Harry A. Verstynen, Jr., NASA Headquarters.

A brief overview is presented of research sponsored by the NASA Aviation Safety Technology Program which may have potential application to general aviation. NASA programs on aircraft tire and brake improvement, aviation meteorology, wake vortex research, crosswind landing research, engine rotor burst protection, and aircraft fire safety research are reviewed.

750505. Aircraft Engine Lube Oil Filtration Study. H. C. Mouwen, Purolator California; and P. Duncan, Swift Aire Lines.

The aircraft engine lube oil filter maintenance practices of a small commercial airline were studied. Engines with known Times Since Over-haul (TSO) were selected and operating hours on the filters were controlled at 50 and 100 hours. The differences in filter pressure drops and particle contamination levels were recorded and a spectrometric analysis was performed on an oil sample from each oil change. The practices evaluated are satisfactory for both the 50 and 100 hours filter periods. The oil spectrometric analyses showed little oil degradation and no relationship between TSO and the recorded data could be obtained.

750506. Thrust Reversers for the TFE-731 Turbofan. William K. Greathouse and Sherman F. Martin, Grumman Aerospace Corp.

Improved design features have made the pivoted-target thrust reverser concept most attractive for modern small turbofans with coaxial flow exhaust systems. These aerodynamic, mechanical and structural design improvements provide 40% or more reverse thrust effectiveness in a simple, light weight, low cost unit that has clean aerodynamic lines and minimum effect on engine performance.

The pivoted-target thrust reverser system, under development at Grumman for the AiResearch TFE-731-2 and -3 engines, is described. Applications include the IAI Westwind 1124, the Gates Learjet 35/36 and the Dassault Falcon 10 aircraft.

In order to discuss the improved design features, an overview of the general installation is presented first to show overall geometry, component hardware, and to define special nomenclature.

750507. A Comprehensive Approach to Icing Certification. T. M. Kutty, Gates Learjet.

During the certification of an airplane, the chances of encountering icing conditions as defined in the Federal

Aviation Regulations (FAR) are so small that the satisfactory performance of an anti-icing system has to be established by methods other than flight tests in FAR icing conditions. The regulations, however, do not specify a set of standard procedures for evaluating the anti-icing capability of a system. The methods used within the industry, therefore, vary very widely in type, scope, and accuracy.

This paper describes an approach used by Gates Learjet that is simple and inexpensive to be within the reach of any manufacturer, and accurate enough to contribute towards the creation of a standard procedure within the whole industry.

750509. Aircraft Safety: The Missing Link—Passenger Education. H. Beau Altman, Interaction Co.

The evolution of Federal Aviation Regulations on passenger safety briefing requirements is reviewed and the importance of the passenger as an integral, functioning component in the aircraft safety system is discussed. From a systems concept, it is contended that passenger safety education has been a missing link. Aircraft accident and behavioral research data are presented to support this contention. Further, the emergence of the field of passenger safety education as a significant, new profession is examined and the current status of government and industry activities related to passenger safety information card design is reported.

750510. The Use of Plastic Foam in Metal Sailplane Construction. Richard E. Schreder, Bryan Aircraft Inc.

This paper explains the advantages of using plastic foam ribs in conjunction with metal ribs in sailplane construction. The paper also details a method for mixing the epoxy required for bonding foam ribs and lists amounts of epoxy needed.

750511. Comparison of Fracture and Fatigue Properties of Clad 7075-T6 Aluminum in Monolithic and Laminated Forms. J. A. Alic and H. Archang, Wichita State University.

Laminated metal-metal composites can have attractive fracture toughness properties; they also offer potentially good fatigue performance. These attributes are reviewed and prospects for improvement discussed. Weak interlaminar bonds are seen to be important, while quite thin layers seem to be most promising for laminates of higher strength materials.

The experimental program utilized 0.033 in (0.84 mm) thick laminae of 7075-T6 aluminum alloy, adhesively bonded. Eight-layer composites were compared with solid sheets of nearly the same total metal thickness. Both fracture toughness and fatigue properties were determined. K_c values of more than double the KI_c for this alloy were observed in the laminates, while fatigue performance as indicated by comparative S-N curves was found to be slightly improved.

750512. Regional Fatigue Environment Study for Commuter Airlines. M. G. Nagati and M. G. Huff, Beech Aircraft Corp.

A fatigue meter data acquisition and processing program has been set up to take advantage of the operational nature of commuter airlines, with the purpose of defining the fatigue life of an aircraft on an individual airline basis.

Commuter airlines operate in a confined geographical area with its particular weather and turbulence characteristics. The result was that in most cases, a substantial increase in the aircraft's fatigue life could be justified in comparison with the one estimated by using a unified turbulence model, which was conservatively established from V-G/VGH recordings from aircraft flying all over the country.

750514. The B-1 Structural Integrity Program. G. P. Haviland, Rockwell International.

This paper details the elements of the B-1 structural Integrity Program for assuring airframe integrity. Unique to the B-1 program is its lack of a full-scale static test article. The paper also mentions the need for comprehensive flight load surveys.

750515. New Directions in Aircraft Propulsor Noise Research. Frederick B. Metzger and Bernard Magliozzi, Hamilton Standard Div., United Aircraft Corp.

Propellers and fans have in the past been tested under static conditions to provide test data for comparison with noise predicted using empirical or theoretically based procedures. This has resulted in noise prediction methodology adjusted to correlate with static test data. Recent tests have shown that the noise of propulsors in flight differs significantly from propulsors tested statically. This paper discusses the current knowledge of propulsor noise from an experimental and analytical standpoint in both static and forward flight operating regimes. Also, the advantages and disadvantages of various approaches to conducting definitive forward flight tests are presented. Emphasis is placed on evaluation of propellers and fans operating at subsonic tip speeds where experimental and theoretical developments can most easily be applied.

750516. Factors Affecting the Noise from Small Propeller Driven Aircraft. Domenic J. Maglieri and Harvey H. Hubbard, National Aeronautics and Space Administration.

The factors affecting noise from small propeller driven airplanes are reviewed to quantify their affects where possible, and to indicate the potential for noise reduction. The main sources of external noise are noted to be the propellers and engines, the airframe being of less importance for both aural detection and community annoyance. Propeller noise is a strong function of tip speed and is affected adversely by non-uniform inflows. Reciprocating engine exhausts are noisier than those of comparably rated turboshaft engines, but their noise can be reduced

by the use of flight certified exhaust mufflers.

Presently, there are no generally accepted engineering methods for development of optimized propellers and exhaust muffler designs from weight and performance penalty standpoints. Flight demonstration results, however, suggest that required noise reductions for future certification should be possible with potentially small penalties.

750517. Public Acceptance of the STOL Demonstration. M. Brenckmann, Transportation Development Agency, Ministry of Transport (Canada).

The events and findings concerning public acceptance during the planning and operational phases of a downtown-to-downtown STOL demonstration service are being reviewed in this paper as a case study on public affair matters in technology innovation. The factors conducive to the successful introduction of future STOL services are more particularly dealt with, on the basis of experience to date.

750518. Commercial Developments in Airborne VLF Navigation. A. Byron Elliott, Global Navigation Inc.

Spurred by a rapidly growing need for long-range and remote area navigation, airborne navigation systems based on continuous wave very low frequency (VLF) transmissions have in a matter of a few years progressed from laboratory curiosity, past simple embodiment of the principle, to the stage of highly sophisticated and very complete navigation equipment. The systems to be discussed utilize the phase-stable transmissions of VLF communications stations and unique frequency transmissions available from some of the Omega network stations. Various phase comparison techniques are utilized to derive the navigational information.

750521. Propeller Modulation Effects on a Scanning-Beam Microwave Landing System. Jack M. Pope, Ames Research Center, NASA; and William N. Staehle, Equipment Div., Raytheon Co.

The results of a systems study and ground test of the effects of propeller modulation on a time-multiplexed, scanning-beam microwave landing system (MLS) are presented. Propeller modulation effects are analyzed in terms of spacing between receiving antenna and propeller, propeller blade width, and propeller speed. Principal study conclusions: (1) scanning beam MLS is susceptible to errors due to synchronous propeller modulation; (2) the number of synchronous interference multiples increases as the number of propeller blades increases and as the data rate decreases; (3) the probability of synchronous interference decreases at higher data rates; and (4) MLS receiver susceptibility to propeller modulation depends upon the dynamic response of the receiver automatic gain control and the respective tracking loops.

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750522. Keyboard Data Entry in Avionics. Charles A. Fenwick and Craig W. Hickok, Rockwell International.

Operating procedures for keyboard data entry in avionics are analyzed. The type of information being entered may be identified either before or after entry of the alphanumeric characters. The keys which are used to identify the type of data may be collected in a centralized control unit or distributed throughout the cockpit adjacent to the associated displays. The Collins NCS-31 and the King KCU 565 navigation and control systems are discussed as illustrations of two sets of choices for operating procedures. Emphasis is placed upon correspondence between the thought processes associated with data entry and the pilot's actions in entering data.

750523. Wind Tunnel and Flight Development of Spoilers for General Aviation Aircraft. W. H. Wentz, Jr. and H. C. Seetharam, Wichita State University; and J. T. Calhoun, Robertson Aircraft.

Wind tunnel tests have been carried out to develop a spoiler lateral control system for use with the GA(W)-1 airfoil with a 30% Fowler flap. Tests show that unfavorable aerodynamic interactions can occur between spoiler and flap for large flap deflections. Providing venting of lower surface air through the spoiler opening substantially improves performance. Results of tests with a number of spoiler and cavity shapes are presented and discussed.

Applications of two-dimensional wind tunnel results to the design of satisfactory manual lateral control systems are discussed.

750524. Design of Low-Speed Airfoils by Numerical Optimization. Raymond M. Hicks and Garret N. Vanderplaats, Ames Research Center, NASA.

A practical procedure for the optimum design of low-speed airfoils is demonstrated. The procedure uses an optimization program based on a gradient algorithm coupled with an aerodynamic analysis program that uses a relaxation solution of the inviscid, full-potential equation. The analysis program is valid for both incompressible and compressible flow, thereby making optimum design of high-speed, shock-free airfoils possible.

Results are presented for the following three constrained optimization problems at fixed angle of attack and Mach number: (i) adverse pressure-gradient minimization, (ii) pitching-moment minimization, and (iii) lift maximization. All three optimization problems were studied with various aerodynamic and geometric constraints.

750526. Drag Analysis Methods for Light Aircraft. Frederick O. Smetana and Delbert C. Summey, Dept. of Mechanical and Aerospace Engineering, North Carolina State University.

The bases for computer programs which calculate by rigorous analytical methods the lift and drag of light aircraft are indicated along with results obtained for

airfoils, complete wings, and fuselages. A method to determine the actual lift, drag, and thrust horsepower experienced during flight is discussed in detail. The latter will be used to verify the analytical predictions for an advanced technology light twin.

750528. An In-Flight Investigation of Nonlinear Roll Control. David R. Ellis and Narayan W. Tilak, Princeton University.

An in-flight simulation was undertaken to study the piloting problems associated with a type of nonlinear control effectiveness which is characteristic of spoiler roll control systems. Typically, the initial response is small or even zero, followed by a narrow region of highly effective control, and a final one of moderate effectiveness.

Results for the landing flare and touchdown, which turned out to be the critical flight phase, indicate that a substantial amount of dead zone and changing effectiveness can be tolerated, but the best level of handling is obtained with linear, aileron-like control.

750529. Flight Mechanics and Pilot Evaluation of Conventional Landings. Edward Seckel and Patrick H. Whyte, Princeton University.

The results are given of an extensive investigation of conventional landing flares in general aviation type airplanes. Experimental landings in a variable-stability Navion have simulated a wide range of parameters influencing flare behavior.

The most important feature of the flare has turned out to be the airplane's deceleration in the flare, and it has been found to be possible to correlate various effects on this in terms of the average flare load factor.

Certain kinds of ground effects are found to be favorable, if they are small and in the right combination. Piloting technique is extensively discussed. Certain implications for design are presented.

750531. Expanded Thermoplastic Core: A New Dimension in Plastics for Structural Applications. Rosemarie Rourke, Norfield Corporation.

This paper deals with the development of a new plastic fabrication method, the Expanded Core process. The resultant products of this process have many unique combinations of features in comparison to other honeycomb structures.

This new process, with variations, lends itself to numerous applications. Its chief advantage lies in the fact that low pressures are required which results in low capital costs.

750532. Damage Resistance of High Modulus Aramid Fiber Composites in Aircraft Applications. J. C. Norman, E. I. du Pont de Nemours & Co., Inc.

Analyses of impact resistance are made for composites reinforced with fibers of high modulus aramid, glass, graphite, and graphite/high modulus aramid hybrids which indicate that the aramid fiber offers advantages over the other materials in thin laminate specimens when measured by Charpy, Izod, and ball drop impact tests while retaining some structural integrity. Use of the high modulus aramid fiber as a hybrid with graphite resulted in higher impact energy resistance than the all-graphite fiber composite.

The fracture characteristics of notched quasi-isotropic high modulus aramid, E-glass, and A-S graphite epoxy lamina and of notched fabric epoxy lamina of aramid and of glass are analyzed. Aramid showed the highest fracture resistance, followed by glass and graphite.

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750533. Graphite Composite Materials Applications in Aircraft Structures. S. L. Cross, Hercules Inc.

Graphite fiber-reinforced composite materials have been evaluated for use in aircraft structural components, primarily as a means of reducing the weight of selected metal parts. Control surfaces, fairings, internal structures, and landing gear have been manufactured, laboratory tested, and, in many cases, flight tested. Weight savings of 15-30% have been demonstrated; and, through less conservative design estimates, savings in excess of 40% appear feasible. Raw material cost has been the pacing item in approaching business aircraft applications; however, current trends show strong potential for cost competitive use.

750534. Ducted Propulsors—Progress in the United Kingdom. D. G. M. Davis, Dowty Rotol Ltd. of Gloucester (United Kingdom).

The concept of the Ducted Propulsor as a quiet propulsive device is relatively new and, because of this, there is a justifiable demand to see evidence that the claims made can be met.

Over the last two years, Dowty Rotol have done a considerable amount of test work and have amassed measured data on thrust, noise, efficiency, cowl drag and windmilling drag. The main part of the paper is devoted to presenting these data in order to answer affirmatively and convincingly the aircraft designers' question—will it work?

To preface this, the paper reiterates the case for the Ducted Propulsor, the idea of which was introduced some time ago. Briefly, it meets the noise regulations predicted to 1980 and beyond, it is lighter than the equivalent Quiet Propeller and costs less. The performance characteristics are about the same but the propulsor affords the aircraft designer more flexibility. Furthermore, it helps to reduce exhaust pollution

Finally, the paper outlines the current program of work to build and test a fully integrated ducted propulsor power plant.

750535. Low Emission, Water-Tolerant Combustor for a Small, All-Weather Turboshaft Gas Turbine Engine. R. M. Wood, J. G. Tomlinson, D. L. Troth and J. J. Petraits, Detroit Diesel Allison

Div., General Motors Corp.

An experimental program was conducted to select a combustion system design for the 500 shp Model 250-C28 turboshaft/turboprop engine. The primary goals were:

1. Capability of complying with the Environmental Protection Agency (EPA) 1979 Class P2 turboprop engine emission standards.

2. Capability of ingesting a 100 ml slug of water in 1/4s without flameout.

The Model 250-C28 engine is an uprated version of the Model 250 (T63 military designation) production engine. The conventional Model 250 production combustor meets the EPA 1979 turboprop emission standards for NO_x and smoke, but unburned hydrocarbons (UHC) and CO exceed the standards. Also, the water ingestion requirement for the Model 250-C28 exceeded the capability of the current technology conventional combustor.

The emission and water ingestion goals of the program were met with a prechamber combustor design. Exhaust emissions measured during testing with a current production engine configuration met all of the EPA 1979 Class P2 turboprop engine emission standards. Engine water ingestion tests with the prototype prechamber combustor exceeded the program goal, and a tolerance level about four times that of the production Model 250 engine was demonstrated.

The favorable results from this investigation led directly to a Model 250-C28 prechamber combustor design that is currently undergoing development.

750536. A Second Generation Turbo-Prop Power Plant. J. B. Houston and D. F. Black, de Havilland Aircraft of Canada, Ltd.

A survey of the design concepts and features of the power plant installation in the de Havilland Aircraft of Canada Dash 7 is presented. The Dash 7 is a 50 passenger, four-engined turboprop STOL aircraft. The UACL PT6A-50 engines, their mountings, intakes and control systems are described. The construction and control system of the Hamilton Standard 24 PF propellers are discussed. A brief description of the accessory systems concludes the paper.

750537. Crashworthiness Investigation of General Aviation Accidents. Richard G. Snyder, Institute of Science and Technology, University of Michigan.

General aviation accident investigations can provide valuable data to the design engineer concerning the crash performance of current models and can indicate needed improvements for occupant protection in future aircraft. Current statistics and the historical background of major investigations during the past 65 years are provided. A five-year study of general aviation accidents occurring in the State of Michigan is used as a basis to illustrate recent findings relative to occupant injury mechanisms, relative crash protection, and crashworthiness performance of current models of aircraft. Results indicate that the degree of structural damage may not relate to the degree of occupant injury when the cabin area remains relatively intact. A primary requirement is documented for adequate upper-torso restraint for all occupants, and the excellent crash performance of such a system is described. Relationships of injuries to structural components are shown, and examples of good fuselage crashworthiness but unsatisfactory seat/restraint systems noted. The primary conclusion is that many fatal and serious injuries still occur in low-velocity impacts where the cabin structure shows little damage but the occupant is inadequately protected from structural contact.

750543. Tri-Gull Amphibian Development. John C. Galizia and David A. Hazlewood, Trident Aircraft Limited (Canada).

Trident Aircraft Ltd. was formed for the specific purpose of completing the development of the Trigull-320 amphibian. This is the account of the development of the aircraft to date as experienced by a newly assembled management and group of designers.

750544. Discussion of an Aeromechanical Gust Alleviation System to Improve the Ride Comfort of Light Airplanes. Eric C. Stewart, Langley Research Center, NASA.

A discussion of an on-going NASA research project of a gust alleviation system to improve the ride comfort of a light airplane is presented. The discussion includes a description of the proposed system which uses auxiliary aerodynamic surfaces to drive the trailing-edge flaps. The results of analytical work on the effects of the system on stability and effectiveness of the system are presented. Static wind-tunnel tests of the system installed in a 1/6-scale model of a popular light airplane are also described. Problem areas which may need future investigation are discussed.

750546. "Melmoth"—An Experimental Private Aircraft. Peter Garrison, Flying Magazine.

"Melmoth," an amateur-designed and built light airplane, has a number of features unusual in general aviation aircraft, aiming to combine comfort, high cruising speed, aerobatic capability and transoceanic range in a single compact machine. Among these are high wing loading, large internal fuel capacity, variable aileron incidence, double-slotted Fowler flap, automatic fuel tank switching, internal cowl flaps, and an all-flying T-tail.

750547. Some Ideas of Vortex Lift. Witold A. Kasper, Engineering Consultant.

In tests on a glider designed for experimenting with vortex generated lift, the author experienced an unknown phenomenon which kept the glider afloat at half the usual sink rate and stalling speed. After study it was realized that a huge vortex had been forming after the stall which explained the presence of additional lift at high angles of attack and low speeds. The implications that this discov-

ery has in terms of improving the slow speed characteristics of airplanes are explained in the paper in addition to a detailed study of the characteristics of this vortex.

750548. Handling and Performance Characteristics of Swept-Forward Flying Wing Aircraft. James J. Marske, Marske Aircraft Corp.

Four unique man-carrying flying wing sailplanes were designed, built, and flown by the author. Special attention was devoted to their stability, control, and aerodynamic efficiency. Of the various designs tested, all exhibited excellent stability. However, pitch and roll control systems with undesirable drag characteristics plagued early experiments. A recent configuration utilizing a swept forward wing in conjunction with a spoiler-aileron roll control system appears to have solved most previous maneuvering problems.

750550. Technology for Reducing Aircraft Engine Pollution. Richard A. Rudey and Erwin E. Kempke, Jr., Lewis Research Center, NASA.

Programs have been initiated by NASA to develop and demonstrate advanced technology for reducing aircraft gas turbine and piston engine pollutant emissions. These programs encompass engines currently in use for a wide variety of aircraft from widebody-jets to general aviation. Emission goals for these programs are consistent with the established EPA standards. Full-scale engine demonstrations of the most promising pollutant reduction techniques are planned within the next three years. Preliminary tests of advanced technology gas turbine engine combustors indicate that significant reductions in all major pollutant emissions should be attainable in present generation aircraft engines without adverse effects on fuel consumption. Fundamental-type programs are yielding results which indicate that future generation gas turbine aircraft engines may be able to utilize extremely low pollutant emission combustion systems.

750551. Steering Analysis of a Three-Axle Vehicle. David J. Olson, International Harvester Co.; and Leonard J. Hunsader, WABCO Construction & Mining Equipment Group.

An analysis of the forces acting on a three-axle vehicle resulted in a computer program that calculated tire forces and minimum turning circle diameter.

The computer program is a valuable design tool because changes in steering geometry can be quickly evaluated. The effect on tire forces and turning circle diameter can be readily determined.

750552. Skid Steering of Crawlers. James E. Crosheck, Deere & Co.

This paper presents the chassis analysis of a crawler in a turn (skid-steer) situation. The analysis accounts for vehicle unbalance, both side-to-side and fore-aft. In particular, the analysis treats the case of a linear variation in track pressure as opposed to the uniform track pressure case discussed in the literature. This variation is found to produce significant differences in the track forces as is brought out in a study of turn geometry parameters and fore-aft unbalance.

Variations in radius of turn, drawbar pull, vertical loads, and external torques are presented for a hypothetical vehicle. This is indicative of studies that can be pursued in more depth.

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750553. Field Service History Analysis for Ground Vehicles. H. D. Berns, Deere & Company.

The historic development of product design analysis is reviewed to highlight the fundamental needs of collecting and analyzing field service histories. These needs and other criteria of an analysis procedure which reduce product development time and costs are discussed. The paper shows how a three level field service history analysis procedure can fulfill the design analysis needs of product engineers.

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750555. Ferrographic Oil and Grease Analysis as Applied to Earthmoving Machinery. Vernon C. Westcott, Trans-Sonics, Inc.

Oil analysis has been used for a number of years to determine the condition of lubricated machinery, and to predict failures from excessive wear of lubricated parts of the machine. The principal technique in use up to the present time has been spectrometric oil analysis. This technique is based on the concept that as a part wears, minute quantities of wear material enter the oil and are dispersed throughout the whole lubricating system. A sudden increase in the amount of a metal in the oil indicates that some part made of that metal has started to wear.

The technique has been successful in several major applications, principally in the railroad industry on diesel locomotives and in connection with the monitoring of aircraft engines. The technique is widely used and has provided warnings of failures before they have resulted in catastrophes. Often the cause of the failure can be corrected before serious permanent damage is done to the machine. As an example, the ingestion of sand, usually caused by a failing air filter, will cause rapid wear in a machine, but if this condition is detected soon enough the air filter can be repaired and the machine saved.

Ferrographic oil analysis is a new technique which goes much further in that it provides information about the size distribution of the particles and also permits the direct analysis of the types of particles, so that the nature of the failure can be determined. For example, it may be determined that the problem is with rolling bearings, or that most likely a gearing system is involved. Further, innocuous causes of high metal content in the oil may be detected and corrected without the necessity of tearing down a complex piece of machinery. The technique is aimed at answering two questions: "Is the machine sick?",

and, if so, "What is the matter with the machine?".

Studies over the last two years have shown that wear particles belong to unique classes and certain types of wear particles are associated with specific modes of wear. An analysis of the wear particle size distribution and the types of wear particles present in the lubricant permits the prediction of failure of a machine and the determination of the nature of the failure.

750556. Synthetic Lubricants for Earthmoving Equipment. William C. Kiefer, Bel-Ray Co., Inc.

Synthetic lubricants are not new breeds of fluids which were suddenly developed because of scarce petroleum oils. They have been available for many years and utilized as lubricants for diversified ranges of specialized applications. These specific fluids were developed with tailored physical and chemical properties best suited to the severe demands of equipment operating under wide temperature range and other hostile environments.

This paper will cover applications on earthmoving equipment such as gear lubrication, hydraulic and torque convertor fluid, engine oils and greases exposed to wide temperature ranges and, especially, low temperatures.

Large, heavy duty earthmoving equipment is being exposed to very low temperature environments, as low as -65° F in some remote areas of the world. This demands lubricants that have better low temperature properties than found in petroleum base types. This paper will cover only those that are best suited to this area of application and those which are economical and readily available.

750557. Solid Waste Disposal and the Challenge Ahead. Richard W. Eldredge, Eldredge Engineering Assoc., Inc.

The earthmoving industry has been the basic supplier of solid waste disposal equipment. Current reports and publications indicate that new alternatives for disposal will conserve land use.

Survey data which reflects current activities and practices notes no head long rush to discard land disposal, in fact there may be no acceptable alternative for much of the waste generated.

The author describes the problem magnitude, comments on alternative disposal methods, and identifies some of the challenges specifically related to the earthmoving industry.

750559. The Composter—A New Development in Waste Disposal. David P. Whitten, Terex Div., General Motors Corp.

A modified Front End Loader has been equipped with a hydrostatic elevating attachment that turns, mixes, and aerates as it windrows solid waste. In mechanizing nature's composting process, time required to compost is reduced and the results are an economical means for organic solid waste disposal. Three types of solid waste applications are highlighted: Municipal Landfills, Animal Waste, and Sewage Sludge.

750560. Observations Concerning On-Site Brake Testing of Large Mining Trucks in British Columbia. V. E. Dawson, British Columbia Dept. of Mines and Petroleum Resources (Canada).

The results of over 600 braking tests carried out on large mining trucks are presented in this paper. The tests were made over the past five years at mine sites in British Columbia on dump trucks having load capacities ranging from 35–200 tons. All tests were made with the vehicles fully loaded operating on downhill grades varying from 6–10%. Stopping distances were measured from the point of application of the service brakes from various initial speeds. The results are adequate, in some cases, to permit extrapolation of the observed values to indicate a likely "runaway" speed of the truck in the event of failure of the regenerative or other auxiliary retarding system.

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750561. Fires on Large Off-Road Vehicles: The Problem and Solution. Ralph B. Stevens, Advanced Products Div., FMC Corp.

A semi-automatic fire protection system has been developed to reduce operator hazards, the cost of repair, and lost production time as a result of fires on large mobile machines. Research of military and industrial fire protection systems for mobile equipment has resulted in a hybrid prototype system that combines optical and thermal fire sensors, logic controls, self-monitoring circuits and an extinguishing system to meet rigorous demands imposed by off-road equipment. The amount and type of fire protection needed for a variety of equipment is explained and a decision analysis matrix provides guidelines and rating scales of fire protection necessary for large haulage trucks and other off-road equipment.

750562. Alarm Indicating Devices. H. T. Vidovic and C. B. Murray, Jr., General Diesel and Equipment, Inc.

An elementary engine alarm system is described which may have had some effect in reducing cylinder head damage. The claim is advanced that many problems encountered with the early system in reality contain hidden beneficial aspects, but the certitude of this is left unresolved. A more complex system is described which can monitor oil levels and contains fault-detecting circuitry.

750564. Design Concepts of the JD770 Motor Grader. L. L. Williams, John Deere Dubuque Works.

In the overall concept of a motor grader, many requirements must be established and met to produce a machine that will efficiently perform the work for which it was intended.

Some of the major design concepts, features and specifications of the new John Deere JD770 Motor Grader are discussed in this paper.

750565. A New Facility for Building Prototype Tractor Shovels. Gordon Fowler, Clark Equipment Co.
Review of various construction, equipment and organization factors considered in the design of new plant facility for fabrication of prototype earthmoving vehicles. Emphasis on eliminating existing problems and maximizing plant efficiency.

750566. Six-by-Six Desert Vehicle. Dennis T. Crowe, Sr., Oshkosh Truck Corp.
The application of all-wheel drive vehicles to the desert environment is not new or unique, but model changes occur that incorporate improvements of components or manufacturing techniques. This paper deals with one specific six-by-six power shift model that was first marketed in 1973. ("Six-by-six" refers to a six-wheel vehicle with all six wheels capable of transmitting power from the engine.) A description of major components and how they are matched may be a useful tool for future designs. The cooling system and tires are the major differences in the desert six by six, when compared to the conventional all-wheel drive units applied to the United States construction market. These are discussed in detail.

750567. Trucks in a Cold Weather Environment. Robert D. Jones, International Harvester Co.
The current energy shortage, coupled with the presence of oil on the north slope of Alaska, has placed trucks in an unusual operating environment. They must be manufactured from materials that can withstand temperatures of -65° F (-54° C), provide a comfortable environment for the driver, and perform efficiently.

750568. Earthmoving Equipment in an Underground Environment. R. Chapman, Domtar Chemicals (Canada).
The purpose of this paper is to describe a room and pillar underground mining operation where conventional surface-type earthmoving trucks and rubber tired loaders are used to load and haul shot rock salt from the mining faces to the primary crusher.

It will also explain the methods used to introduce this equipment into the mine, pointing out some of the differences between a surface and an underground operation.

Some of the methods used to maintain an acceptable quality of the underground atmosphere are discussed and the additional maintenance required to keep this equipment in proper working condition is indicated.

750569. An "In-House" Technical Forecast. W. J. Lux, John Deere Dubuque Works.
This paper describes a technical forecasting program that was used at the John Deere Dubuque Works' Engineering Department and—even though we have not proven its effectiveness—tells you why we think it works. It also tells what construction machinery will probably be like 20 years from now.

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750570. Factors Influencing Engineers' Productivity. J. Wayne Deegan, University of Iowa.
This paper evaluates some popular management techniques generated by social scientists and considers some lesser known findings more specifically related to the engineering profession. The author indicates both for engineers and engineering managers, methods for discovering and dealing with individual psychological needs.

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750571. Integrated Construction—A Future for Independent Contractors. Frank B. Willis, H. B. Zachry Co.
An opinion is offered on what an independent contractor must do to survive in the future. The present era of dynamic, ever changing technology and business practices requires the independent contractor to be capable of providing a complete and finished product for a client from concept to utilization, including design, financing, land acquisition, insurance, construction, operation and maintenance. Thus, every single phase of construction development will be integrated into an entity.

750572. Development of a One-Piece Rim for Earthmover Tires. Wm. T. Anniss, Electric Wheel Co. Div., Firestone Tire & Rubber Co.
The off-highway, 15 deg bead seat tire and its 15 deg tapered bead seat drop center rim is a new concept for today's earthmoving vehicles. The drop center rim concept offers significant advantages over the more common removable flange rim in weight reduction, safety, and durability. This paper describes those advantages, as well as the development and testing of the rim and tire design.

750573. Temperature Buildup and Radial Spring Rate Properties of Six Off-The-Road Tires. Ben J. Brookman and Peter Skele, U.S. Air Force.
Temperature buildup tests and load deflection tests have been conducted on six tires, three sizes with one bias and one radial ply carcass construction per size. Temperature buildup curves are given for each tire at various conditions. Curves of load versus deflection are shown for each tire during both loading and unloading. Loss energies occurring during the loading-unloading cycle are tabulated.

750574. Work Capability Factors for Dozer and Loader Tires Operating in Load and Carry Service. David V. Cvengros and Richard J. Olsen, Goodyear Tire & Rubber Co.
Demands of the earthmoving industry for in-depth tire knowledge and performance capabilities has placed increased responsibility on the tire manufacturer for

establishing operating limits. The challenge of meeting these demands has resulted in an increasing amount of controlled tire testing conducted under simulated field conditions. One of the areas of required information has been for the establishment of Dozer and Loader tire capabilities when operating in Load and Carry service.

Since tire heat becomes a major potential problem in Load and Carry service, a method was required to determine the performance capabilities of Dozer and Loader tires so that optimum tire life could be achieved. This paper covers the need for tire limits; basic Dozer and Loader tire design requirements; the method established for determining tire capabilities in Load and Carry service, and finally the factors differentiating this rating system from the TMPH system which is used for transport type vehicles.

750575. A Bigger Payload from Steel Foundries. George P. Bertino and Gerald B. Thelen, Wehr Steel Co.

The existing market conditions place heavy demands on the steel foundries to increase their capacity and output. Expansion hinges on the ability of the foundry to "earn the dollar" to permit the modernization of existing facilities and construction of new plants. It also requires that the foundry industry modernize its production methods and techniques, update its equipment, and that the consumer engineer assist in developing casting design features that will be more readily adaptable to the capabilities of the foundry operation.

"A Bigger Payload from Steel Foundries" requires more than physical expansion—it demands cooperative and intelligent endeavor on the part of foundry management and consumer engineering.

750576. Air Film Systems as Applied to the Manufacture of Heavy Equipment. Terry Baker and Shelby Morley, Rolair Handling Systems, Inc.

The air film industry, although relatively new, has been widely accepted by manufacturers of heavy equipment. The unique ability of air film equipment to practically eliminate friction and facilitate the movement of heavy, bulky items economically has contributed to the evolution of many new manufacturing techniques.

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750578. The Cost of Moving Overburden By Various Machine Systems. T. S. Colvin, C. E. Anderson and W. F. Buchele, Iowa State University.

An overview of the Iowa State Coal Project is presented. Draglines and scrapers are compared for energy efficiency in stripping coal. Survey results on scrapers are presented which show diverse production and cost relationships indicating that many factors other than size of machine, haul distance, and grade are important.

750579. Earthmoving Truck History and Progress. Ralph H. Kress, Kress Corp.

Until approximately 50 years ago horses and manpower were considered the best means for earthmoving. Progress from this point came in the late 1930s as off-highway trucks began to replace on-highway trucks. The development of engines with more horsepower moved the industry ahead. Today earthmoving is made more complex for we must consider not only the advances in earthmoving equipment, but also if equal advances have been made in auxiliary equipment and manpower to allow maximum efficiency.

750580. Colony Development Operation Oil Shale: Mining and Recovery of Oil. Paul W. Marshall, Atlantic Richfield Co.

The paper begins with a brief history of Colony Development Operation, followed by an overview of the planned commercial mine and plant complex which includes artists' conceptions of the designed layout. The four basic areas of a commercial complex—mining, crushing facilities, processing facilities, and processed shale embanking and revegetating—are presented. The commercial operation, two-bench, room-and-pillar mining system design is described in detail. The mining cycle of drilling, blasting, loading, hauling, scaling, and roof bolting is discussed, as well as the mobile mining equipment which is being designed and will be utilized. Some of the detailed Colony pilot mine engineering testing programs are then introduced, and their effects on the commercial mining of oil shale are enumerated.

750582. Some Effects of Legislation on Equipment Needs in the Reclamation of Surface Mined Land in the Midwest. James R. LaFevers, Argonne National Laboratory.

In the past, there was little need for changes in machinery design specifically for surface mining. However, the requirements imposed by land reclamation legislation since the 1940s present problems that cannot be handled readily by conventional equipment. For the long run, new types of equipment should be considered. In the meantime, research efforts should be devoted to redesigning, enlarging, or modifying existing equipment.

750583. Lubricant Contaminants and Their Effects on Bearing Performance. Brian Fitzsimmons and Brian J. Cave, The Timken Co.

Contaminants that find their way into the lubrication system of a mechanism can have significant adverse effects on the useful life of the antifriction bearings in the application.

This paper provides a discussion of the more common types of solid and liquid lubricant contaminants and the possible sources from which they originate, plus the different modes of premature bearing damage that can result. Some case histories of applications plagued with contaminated lubrication problems and the resulting difficulties encountered with bearing performance are also reviewed.

These views are primarily limited to past experience

with tapered roller bearings manufactured from case hardened materials.

750584. Link Pin Seals on Off-Highway Equipment. R. H. Prachel and I. L. McMillen, Garlock, Inc.

Radial lip type exclusion devices of various elastomers and configurations have been available to designers for decades. In recent years the steel-encased polyurethane rod scraper has become popular in the most difficult service environments of hydraulic cylinders on mobile equipment.

An adaptation of this proven cylinder component is now extending lubrication intervals and life of critical linkage pins and bushings at oscillating pivot points on off-road construction and materials handling equipment. Its purpose is to exclude foreign material such as dirt, water, stones while retaining lubricants at the pin and bushing interface.

The polyurethane material with its high tear strength and abrasion resistance extends seal life. Yet, its configuration allows for lubrication at longer maintenance intervals. Current information is that maintenance intervals have been reduced by 90%

Future adaptations of this technology might provide a sealed, lifetime-lubricated pin and bushing assembly.

750585. The Application of Centralized Lubrication Systems to Mobile Equipment. Bill Mueller, Ritter Engineering Co.

Recent developments in centralized lubrication systems have made them more compatible with the operational demands of the construction industry. This system delivers the correct amount of lubrication to each bearing, can warn the operator in the event of a lubrication failure and directs maintenance personnel to the problem area during a scheduled downtime. It has a wide variety of pumping methods, controls and monitors. Safety of personnel, continuous lubrication, reduced downtime, reduced usage of lubricants, longer machine life and higher profits are the results of a good lubrication program.

750586. Challenges of Short-Haul Air Transportation. T. L. Galloway, Ames Research Center, NASA; and J. A. Stern, Douglas Aircraft Co.

Short-haul air transportation is one of the most challenging of all modes of transportation. The short-haul passenger market represents approximately 40% of the total U.S. domestic market. This market can be classified by passenger density. A Douglas study, funded under a NASA contract, is reviewed. This study indicates potential means for successfully meeting the challenges in the market with under 500 daily passengers. Initially, the market is investigated and realistically defined; then aircraft requirements that are economically viable and environmentally acceptable are established to satisfy the market.

To meet the challenges of this market, the need for economic viability and environmental acceptability requires the careful balancing of performance, technology, and design-to-cost concepts. A general aviation manufacturer participated in evaluating design-to-cost options and three airlines provided guidance for operating realism.

750587. Design of Short Haul Aircraft for Fuel Conservation. M. K. Bowden and H. S. Sweet, Lockheed Georgia Co.; and Mark H. Waters, Ames Research Center, NASA.

Current jet fuel prices of twice the 1972 level have significantly changed the characteristics of airplane design for best economy. The results of a contract with the NASA Ames Advanced Concepts and Missions Division confirmed the economic desirability of lower design cruise speeds and higher aspect-ratio wings compared to designs developed in the by-gone era of low fuel price. Evaluation of potential fuel conservation for short-haul aircraft showed that an interaction of airfoil technology and desirable engine characteristics is important: the supercritical airfoil permits higher aspect ratio wings with lower sweep; these, in turn, lower the cruise thrust requirements so that engines with higher bypass ratios are better matched in terms of lapse rate; lower cruise speeds (which are also better for fuel and operating cost economy) push the desired bypass ratio up further. Thus, if fuel prices remain high, or rise further, striking reductions in community noise level can be achieved as a fallout in development of a 1980s airplane and engine.

Analyses of the above trends are presented, along with the effects on fuel consumption of design field length, powered lift concepts, and turboprop as well as turbofan propulsion. Assessment is made of the most appropriate aircraft developments in the low/medium density short-haul arena as well as the high density short and intermediate range markets.

Recommendations are made for further work which will support fuel conservation, including active controls for high aspect ratio wings, and development of engines which are most suitable for lowest system costs at high fuel prices.

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750589. Turbine Engine Parts Life Improvement Through Thrust Management. Calvin O. Spear, Pratt & Whitney Aircraft Div., United Technologies Corp.

The general subject of turbine engine thrust management includes the selection and setting of engine thrust. Flight manual information available to the operator of turbine powered aircraft defines the methods for selecting thrust levels with relation to a predetermined minimum airplane performance standard. The logical selection of thrust level to be used requires an understanding of the resultant effect on engine parts life as well as the effect on operating economics.

750590. Monitored Thrust is a Critical Element in Effective Operations. Bruce Aubin, Air Canada.
This paper is an attempt to establish the rationale for monitored, or reduced, thrust operations in Air Canada and their effect on safety, reliability, aircraft performance and economics. It explains why an approach to operating at less than maximum takeoff thrust has been developed. It demonstrates the effects of monitored thrust on power plants, operating temperatures, and training procedures. Lastly, the paper explains how monitored thrust will produce an improvement in the environment and how it achieves an incremental saving in fuel.
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750592. NASA Refan Program Status. K. L. Abdalla and J. A. Yuska, Lewis Research Center, NASA.
The objective of the refan program is to demonstrate the technical feasibility of substantially reducing the noise levels of existing JT8D powered aircraft. The program consists of the design, manufacturing and testing of the refan engines and modified nacelles and airplanes. Experimental testing has been completed for the refan engine both at sea level and at altitude conditions. Ground testing for the B727 side- and center-engine installations and flight testing of the DC-9 with refan engines and acoustic nacelles have been performed. Analyses of the test results are in progress. Preliminary results presented in this paper show that substantial noise reductions were achieved.

750594. Status Report on NASA Two-Segment Approach Program. D. G. Denery, K. R. Bourquin, F. J. Drinkwater III, F. H. Shigemoto and K. C. White, Ames Research Center, NASA.
NASA, in cooperation with the FAA, is evaluating the two-segment approach as a routine procedure for reducing aircraft noise. The program calls for separate flight evaluations using a 727 and a DC-8, and an extrapolation of these results to determine the adaptability of the technique to the rest of the fleet. After a review of the total program, this paper presents (i) the profile and procedures developed and the noise reduction achievable, (ii) the vortex characteristics behind an aircraft on a two-segment path, and (iii) cost estimates for retrofitting aircraft with two-segment avionics.

750595. Analysis of the Costs, Effectiveness, and Benefits of Aircraft Noise Reduction Programs. Harvey B. Safeer, U.S. Dept. of Transportation.
This document describes the results of cost effectiveness, marginal benefit, marginal cost, and total cost analyses with respect to several noise abatement options being considered by the United States government, including retrofit of aircraft which do not meet the noise level limits of Federal Aviation Regulation Part 36.

750596. 10 Years of STOL—The Twin Otter's First Decade. M. C. W. Davy and P. S. Martin, De Havilland Aircraft of Canada, Ltd.
The Twin Otter was designed as a utility bushplane for operation in the Canadian north. While it has fulfilled that role, it has also been widely adopted for use in urban commuter services which do not demand its STOL and rough field capabilities. Now, after 10 years, these commuter services are widening in scope to the point where these virtues, hitherto unused, are becoming significant. The Twin Otter, by its continued presence over this decade, has helped mould the STOL services promised for the next.

750598. Short Haul Transportation-The Helicopter's Time is Now. R. F. Daniell and R. E. Warren, Sikorsky Aircraft Div., United Aircraft Corp.
The solution to the short haul cost/benefit dilemma is Federal Government funding of system development costs. One means of introducing VTOL to short haul transportation would be development of the S-65C multi-mission helicopter with customers sharing development costs.

750599. Airtransit's First Six Months of Operating the Canadian STOL Demonstration Service. Roy B. McCormack, Airtransit Canada.
A complete STOL (Short Take-off and Landing) system is currently providing public transportation service between the urban centres of two large Canadian cities. Passenger and public reaction, plus operating experience in a competitive environment is providing some interesting data, useful in developing future STOL systems as an important component in the improvement of transportation in general. The Demonstration is showing that STOL systems are capable of quickly providing fast, convenient, short-haul service, while at the same time respecting the composite concerns of society, encompassing air-pollution, noise, land-use, energy-consumption and economics.

750600. Whither All Weather: An Airline Engineer's Point of View. O. R. Evans, United Airlines.
A brief listing of major elements of the ground, airborne and other elements of the All Weather Landing System is presented. The chronology of growth in the use of this system by a major trunk airline in the last decade is reviewed. Problems considered by the author to be basic to further deployment and development of the system are discussed and tentative solutions to these problems are suggested, namely:

1. Continuous recording and public dissemination of Runway Visual Range data for all Category II and III periods at existing and proposed runways of these Categories is suggested to provide the most cost-effective basis for decisions regarding further deployment of ILS systems and MLS systems.

2. It is recommended that an industry group be convened to review and, probably, revise certification requirements for aircraft intended to operate below

Category II minima in order to break the stalemate presently inhering in those activities.

750601. Whither All Weather: An Airplane Manufacturer's Point of View. Automatic Landing (Autoland) Systems—What's Ahead. Harold N. Tobie, Boeing Commercial Airplane Co.

Automatic landing has been developed to the point where all the wide-bodied jets have it as basic equipment. The techniques presently employed are generally founded upon the technology of the last two decades — especially with respect to analog computation and gyroscope references. Several new techniques are now available which can substantially improve the autoland systems for the next generation of transport aircraft. These include airborne digital computers, the use of integrated air-data and strapdown airplane motion reference systems, expanded use of automatic system test, and the development and employment of the Microwave Landing System (MLS). These new technology developments promise to provide expanded operational benefits, reduced maintenance, and increased availability over that of contemporary autoland systems.

750602. Whither All Weather: The Airlines' Point of View or A Review of All Weather Acronymity. Siegbert B. Poritzky, Air Transport Association of America.

A brief review of the airline industry's viewpoint on the all-weather operations program. The paper describes airline policy views on landing guidance requirements, on implementation of ground and airborne all-weather facilities, and on the relationship of the Microwave Landing System to all-weather operations. The paper discusses some necessary characteristics of flight control systems and new cockpit displays for the achievement of more complex and more efficient approaches to runways. The paper expresses an airline man's views with respect to Independent Landing Monitors, visibility enhancement devices, and Air Traffic Situation Displays.

750604. Whither All Weather: The Pilot's Point of View. A. M. Reeser, American Airlines.

The author has been continuously involved with the development and implementation of Category I and II approach operating procedures for American Airlines. This paper describes the Industry's success to-date and proposes a more economical means of attaining CAT IIIa capability.

750605. Quite Clean Short-Haul Experimental Engine (QCSEE) Design Rationale. A. P. Adamson, General Electric Co.

The principal design features of the NASA QCSEE Under-The-Wing and Over-The-Wing powered lift propulsion systems are given. In the UTW engine, these include noise reduction features, a variable pitch low pressure ratio fan, a fan drive reduction gear, an advanced core and low pressure turbine with a low pollution combustor, a digital control, and advanced composite construction for the inlet, fan frame, fan exhaust duct, and variable area fan exhaust nozzle. The OTW engine is similar but has higher fan pressure and a fixed pitch fan. Both engines are scheduled to be fabricated and tested starting in 1976.

750607. Installation Effects on the CF6-50 in the YC-14 Aircraft. Richard K.Tuten, Francis R. Housley and Paul J. Hess, Aircraft Engine Group, Div., General Electric Co.

Design of the YC-14 over-the-wing nacelle, utilizing the CF6-50D engines, presented unique engine installation conditions which have been accommodated with very minor impact to the baseline commercial engine design. Major installation features which affect the engine are reviewed including engine mounting, engine/aircraft deflections and nacelle sealing, effect of the confluent-flow exhaust nozzle on engine cycle matching, and inlet/thrust reverser/engine compatibility. Design solutions and planned testing to evaluate the installation are discussed.

750608. Noise Reduction of EBF Propulsive-Lift Systems. J. S. Gibson, Lockheed-Georgia Co.

In a recently completed program, static and wind tunnel measurements have been made of the basic noise, noise reduction, and performance characteristics of externally blown flap (EBF) propulsive-lift systems. The static tests were performed on an outdoor model rig. Noise evaluations were made for parameters such as basic system geometry, flap slot dimension variation, elimination of flap slots, sweep angle variation, passive flap trailing edge modifications, active (blowing) trailing edge modifications, and for an ejector/decayer exhaust system. The wind tunnel evaluation determined forward speed effects on EBF systems noise characteristics. The results from the experimental programs are discussed as to their application to full scale short haul aircraft.

750609. Full-Scale Upper-Surface-Blown Flap Noise. L. J. Heidelberg, L. Homyak and W. L. Jones, Lewis Research Center, NASA.

A highly noise suppressed TF 34 engine was used to investigate the noise of several powered lift configurations involving upper-surface-blown (USB) flaps. The configuration variables were nozzle type (that is, slot and circular with deflector), flap chord length, and flap angle. The results of velocity surveys at both the nozzle exit and the flap trailing edge are also presented and used for correlation of the noise data. Configurations using a long flap design were 4 dB quieter than a short flap typical of current trends in USB flap design. The lower noise for the long flap is attributed primarily to the greater velocity decay of the jet at the flap trailing edge. The full-scale data revealed substantially more quadrupole (V^8) noise in the region near the deflected jet than observed in previous sub-scale tests.

750610. An Overview of Low Medium Density Short-Haul Air Transportation Policy Implementation. Frederick R. Mazzitelli, Grumman Aerospace Corp.

In recent years several government and industry groups (DOT, CAB, NASA, M.I.T., AAC, etc.) have attempted to define policy and recommendations for the nation's short-haul low/medium density air transport needs.

This paper is an attempt to determine what plans have been recommended, what impact these plans have had on the industry, and what remains to be done. The writer found a diversity of opinions within the industry on the key elements which would form the foundation of a short-haul air transport policy.

The writer has taken the liberty of presenting his own conclusions, which he hopes will stimulate the industry into positive policy action.

750612. Maximum Installed Engine Utilization Through Disciplined Health Monitoring. Heinz W. Bart and Alois B. Nadler, SWISSAIR Transport Co., Ltd. (Switzerland).

Many airlines find themselves at present in a transition period with regard to Engine Health Monitoring. The manual concepts used up to now are being replaced by computerized versions and almost parallel to this comes the introduction of the "On Condition Modular Maintenance." The new High Bypass Engines (engines of the 3rd generation) along with the 2nd generation engines, were designed for "Modular Maintenance." As a result, the efforts toward achieving an automatic engine performance control were also intensified. These new ideas of engine monitoring were repeatedly considered in determining the Modular Maintenance Concept.

Both in the past and at present, airlines have to some extent applied very different engine trend monitoring methods, in theory and in practice. This shows that even good methods are not universally suitable.

Swissair, which is completely autonomous on the one hand but which works in cooperation with the larger unit of KSSU, has specific problems in the exchange of information with regard to Engine Health Monitoring. We should like to explain the basis of Swissair's various Health Monitoring methods.

750613. Engine Maintenance Management Program Requires Information. Loren C. Ellis and Ralph H. Johnson, United Airlines.

"Maintenance Management Programs" for aircraft and their engines have changed in the past 5 years. The maintenance programs have expanded from the hard time limits and on-condition sampling techniques of the 1960s to include condition monitoring (fly to malfunction). The Boeing 747 and Douglas DC-10 went into service using an on-condition maintenance program. The next generation of aircraft will in all probability go into service with a complete "Maintenance Management Program."

The cornerstone of any maintenance/reliability program is an effective information collection, analysis and dissemination system. The collection of information from the many and varied sources has its problems. All too frequently the data is too little, too late, wrong format, inaccurate or incomprehensible.

This paper will review the systems United Airlines uses, or is developing to gather and distribute the information required to support aircraft and engine "Maintenance Management Program."

750615. Future Hydrogen Fueled Commercial Transports. A. J. K. Carline, General Dynamics Corp.

Liquid hydrogen has been proposed as an alternate fuel for aircraft to supplant our dwindling and increasingly costly and insecure hydrocarbon fuels. It is plentiful in supply, recyclable after combustion, low in pollutant and toxic products, high energy content per unit mass, and compatible with state-of-the-art engine technology. Its low density, storage and handling problems, uncertain costs, and safety aspects are facets that have to be dealt with before widespread application is accepted.

This paper outlines some of the airplane design problems and economic aspects of subsonic commercial transports that might be evolved using liquid hydrogen as fuel. Both short and medium haul applications are considered and it will be shown that whatever the category in terms of size and range, these aircraft can compete with equivalent concepts utilizing conventional hydrocarbon jet fuels.

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750616. The Spanloader Advanced Transport Concept. R. H. Lange, Lockheed-Georgia Co.

Utilizing the background acquired in the development of the C-130, C-141, and C-5 aircraft, the Lockheed-Georgia Company has maintained a continuing effort in the conceptual and preliminary design of advanced transport configurations with the overall objectives of improving the efficiency and flexibility of aircraft as cargo carriers. Of a variety of innovative design concepts incorporating technology advances in all applicable areas, the Spanloader concept is one of the most promising for future heavy logistics aircraft. This paper presents a description of the Spanloader design concept, performance characteristics, and mission flexibility. Alternate designs are presented including the use of hydrogen fuel and nuclear propulsion.

750617. Advanced Supersonic Transport. R. D. Fitz-Simmons and R. L. Roensch, Douglas Aircraft Company—McDonnell Douglas Corporation.

Comparisons are presented between the last U.S. SST design and results of recent progress on an advanced supersonic transport design. The results are shown of changing from a double-delta 2.7 Mach configuration to a modified arrow-wing 2.2 Mach design. Information is presented covering increased range, lower operating cost, reduced technical risk, and noise levels that meet antic-

ipated requirements of society.

The main emphasis in this paper is on an aerodynamic lift-to-drag ratio of 10 and how this high level of aerodynamic cruise efficiency can be substantiated for a tailored design.

750618. Future Lighter-Than-Air Concepts. John J. Schneider, Boeing Vertol Company.

During the early 1930s, the rigid airship was potentially the Queen of the Skies. The design, manufacturing, and operational techniques and the facilities had been developed over a 30-year span to the point where the airship easily exceeded contemporary airplanes in range and payload, and even productivity as well. Through a combination of circumstances, failures, and political expediencies, development of the rigid airship was terminated while development of the airplane and its propulsion systems accelerated at a tremendous pace.

There have been a number of attempts throughout the world in recent years to initiate airship development. The need for reduced energy usage and lowering of pollution, coupled with the need for transporting large, heavy, indivisible loads, do appear on the surface to be satisfied by the unique characteristics of the airship. The Boeing Vertol Company, as part of its diversification efforts, has attempted to shed some light on the feasibility of advanced airships in the long-range, freight-transport operations of today and tomorrow.

This paper examines the lighter-than-air situation today, presents a historical overview of the airship, and discusses the possible uses for future airship concepts. Technical and operational characteristics of conventional and hybrid concepts are discussed, as well as results of a parametric analysis of advanced airship concepts indicating speed and cost trends of both conventional rigid and partially buoyant, hybrid airship concepts.

750619. Design of Jet Engine Rotors for Long Life. S. A. Sattar and J. T. Hill, Pratt & Whitney Aircraft Div., United Aircraft Corp.

Jet engine rotors are the most highly stressed large volumes of material in the engine. They possess millions of inch pounds of kinetic energy at normal speeds. Considerable care in design and analysis must be taken to ensure that the parts do not fail over the full life cycle of the engine. In this paper, major design criteria are identified and discussed, with special emphasis on the long-life aspects of disk design methodology. The role of fracture mechanics is discussed as it applies to intrinsic material defects as well as the residual life of the part after crack initiation. Future trends, including the impact of powder metallurgy on design, and retirement of disks for cause are discussed.

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750620. Improving Performance Retention of High Bypass Engines. Norman Epstein, and Paul J. Hess,, Aircraft Engine Group, General Electric Co.

The observed revenue service deterioration characteristics of the CF6-6D engine are analyzed to determine the detailed causes of the SFC and EGT increases. Cruise trend data from DC-10-10 revenue service operations and maintenance test cell results are utilized to define deterioration status. Effects of design changes and installation losses are included. Deterioration rates are seen to be reasonable compared to previous airline experience. Test results are presented for systematic performance field restoration of a deteriorated engine. Preliminary revenue service results are presented for the CF6-50 engine, the CF6 growth engine, which is installed on the DC-10-30, A300B and 747-200.

750621. Engine Maintenance Cost Reduction Through Improved Component Design and Development. C. T. Cravens, R. W. Flickinger and R. M. Murphy, Boeing Co.

High maintenance costs of the three 40,000 lb. thrust class aircraft engines manufactured by Pratt and Whitney, General Electric, and Rolls-Royce are discussed. Primary emphasis is on existing engine problems which contribute to high shop visit rate. Maintenance cost in terms of monetary value is not discussed. Concludes that increased emphasis on total life cycle durability is necessary by the engine manufacturers. Recommends higher level of priority be given durability in design and analysis, pre-production proof-of-design testing, and engine program management.

750622. Airport Ground Access: An Overview of Current Modes. H. R. Ross, Howard R. Ross Associates.

Airport access systems are defined in four categories: distribution within airports; circulation within airport complexes and environs; access to the airport complex from remote points in the urban area; and regional high speed systems. The concept of airport access, and difficulties associated with special purpose solutions outside the general urban transportation problem are addressed. Systems that are available, or are under development, for each category are discussed, and the status of development of more advanced systems is described. Some of the systems reported include moving walks, high speed moving walks, loops, shuttles, remote parking links, special purpose access links, and high speed regional systems.

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750623. Planning, Implementation, and Operation of the Philadelphia-Lindenwold Line. Robert B. Johnston, Port Authority Transit Corp. of Pennsylvania and New Jersey.

Through careful planning and implementation the Delaware River Port Authority has developed a highly successful mass transit system, the Philadelphia-Linden-

wold Line. They have realized their goal of creating a rapid transit line which would win the patronage of potential passengers and be constructed and operated within the economic resources of the Authority.

The one to six car trains are operated by a one man train crew who is, in fact, part of the automated or computerized process. He notifies the computer as to the length of the train; opens and closes doors; determines the length in time of each stop; initiates acceleration; and can eliminate station stops. The computer prevaling determines train speed for each track section and right of way conditions; causes the train to decelerate at the optimum rate; and stops at the station with the center of the train at the center of the platform.

The Lindenwold Line has demonstrated that motorists will leave their cars if superior transportation is provided; quality transit service can reduce air and noise pollution and conserve energy; traffic congestion can be reduced; technology is now available to create desirable rapid transit service, and that rail rapid transit can be planned, constructed, and efficiently managed to meet operating and maintenance costs out of the fare box.

750624. The Tampa and Seattle-Tacoma Airport Transit Systems. Phillip R. Gillespie, Western Electric Corp.

The Tampa and Seattle-Tacoma Intra-terminal transit systems have been in service long enough to judge the validity of their concepts and the success of their designs. These two systems have been accepted by the Authorities that own and operate them. They have excellent safety and performance records. The public accepts their driverless cars routinely.

The two systems are described and compared. They are similar in many respects but differ in their basic application to the airports, one being a shuttle and the other a loop system. As a result of their specific application, the automatic control systems differ.

Operating and performance summaries are given. Both systems provide the same level of service and both have an availability over 99%.

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750627. Ground Transportation System for Bradley International Airport. John J. Spaulding, Connecticut Dept. of Transportation.

An automatically controlled transit system is being installed at Bradley International Airport. The system has two purposes: demonstration of automatic transit for urban applications, and transportation from a remote parking lot to the airport terminal.

The 0.7 mile guideway includes both at-grade and elevated sections. A 550 ft bypass at the intermediate station simulates an off-line passenger terminal. Provisions for extension of the guideway to serve future facilities have been included.

The two 25 ft long vehicles are each powered by two 60 hp electric motors. An on-board computer controls the operation of the vehicle. The vehicles are air-conditioned and have two-way communication capabilities.

Design of the guideway began in November 1973. Construction of the guideway was begun in July 1974 and was essentially complete in December 1974. The construction was completed in April 1975 when the system was energized and testing begun. Public operation is scheduled to begin in November 1975.

750628. Engine Design Considerations for 2nd Generation Supersonic Transports. Robert A. Howlett, Pratt & Whitney Aircraft Div., United Aircraft Corp.

The environmental and economic goals projected for advanced supersonic transports will require revolutionary improvements in propulsion systems. Variable cycle engine concepts that incorporate unique components and advanced technologies show promise in meeting these goals. Pratt & Whitney Aircraft is conducting conceptual design studies of variable cycle engine concepts under NASA sponsorship.

This paper reviews some of the design considerations for these engine concepts. Emphasis is placed on jet noise abatement, reduction of emissions, performance improvements, installation considerations, hot-section characteristics and control system requirements. Two representative variable cycle engine concepts that incorporate these basic design considerations are described.

750629. The NASA Research Program on Propulsion for Supersonic Cruise Aircraft. Richard J. Weber, Lewis Research Center, NASA.

Since 1972 NASA has pursued a program aimed at advancing the technology and establishing a data base appropriate for the possible future development of supersonic cruise aircraft. This paper briefly reviews the objectives and status of the propulsion portion of the program. Building upon a continuing series of propulsion system studies, research activities are under way in noise and pollution reduction, inlet stability, and materials.

750631. AST Propulsion Comparisons. R. D. FitzSimmons and W. T. Rowe, Douglas Aircraft Company, McDonnell Douglas Corporation.

Studies recently completed for NASA show significant improvements in duct heating turbofans and low-bypass turbojets for an advanced supersonic transport. Dual-valve variable-cycle engines (VCE) prove to be non-competitive; however, an emerging double-bypass dual-cycle VCE concept is reviewed which does indicate range improvements that are possible. It is 1985 technology and would require extensive development.

Engine availability in the United States, as important to program success as technology or economics, is discussed. A fan derivative of an improved-technology Rolls Royce Olympus engine is also considered.

An interesting case is developed showing that an Olympus fan derivative on a Douglas AST design offers an earlier U.S. SST possibility than heretofore thought

possible. This might be important if airline pressure should mount as a result of overwhelming public demand for Concorde supersonic travel.

750632. Supersonic Transport Development Considerations. Richard L. Foss, Lockheed-California Company.

The impact of supersonic commercial service to be provided by the Concorde and TU144 SST is going to demonstrate throughout the world the advantages offered by supersonic travel for both business and recreation. Public acceptance will stimulate interest to proceed with a second generation design that meets updated economic and ecological standards. This paper reviews some of the design considerations that are pertinent to this next SST aircraft. Design variables include productivity and cost as affected by cruise speed choice, range and payload selection, and impact of advanced airframe and propulsion technology. A new concept SST is described, and its operational characteristics are discussed; the design meets all economic and ecological goals. A broadened technology data base will be needed; current technology study efforts are making progress, but acceleration of this phase should be considered. Beyond the technology development phase, the SST, or any other new long range transport program, will need new and innovative means for providing financial support. The problem and a possible solution is discussed. Timing for the next generation transport is examined in light of current economic affairs, existing aircraft in service, and lead time needed for SST development.

750633. The Perceived Needs of the Short-Haul Air Carrier. Howard C. Tinney, Boeing Commercial Airplane Company; and Robert B. McIntyre, de Havilland Aircraft of Canada, Ltd.

This presentation examines four different airplane fleets from the standpoint of the 1980 needs of regional short-haul air carriers in balancing passenger satisfaction, operating economy, and good community relations for replacement of their present turboprop equipment.

The four different fleet mixes examined are:

All-100-seat fanjets

100-seat fanjets plus 70-seat fanjets

100-seat fanjets plus 50-seat fanjets

100-seat fanjets plus 50-seat quiet turboprop STOL aircraft

The authors believe that a fleet of 100-seat fanjet and 50-seat turboprop aircraft would best meet the perceived needs of a short-haul carrier in serving a typical turboprop network, for the following major reasons:

Provide better service with more daily departures than the fleet with 70-seat and 100-seat aircraft.

Save substantial amounts of fuel annually compared with the next most fuel-economic fleet mix.

Save significantly on airplane-associated operating costs over the most economical alternative fleet mix.

Reduce the noise exposure at small-city airports compared with the next quietest alternative and with the existing service.

750670. A Technical Report of the 1975 Union 76 Fuel Economy Tests. D. T. West, T. Wusz, F. T. Finnigan and R. J. Askevold, Union Oil Co. of California.

Union Oil Company of California tested 106 new 1975 domestic and foreign vehicles for on-the-road fuel economy using the Fuel Economy Measurement—Road Test Procedure—SAE J1082. This paper gives the results of the test and discusses vehicle selection, procurement, break-in, tune-up, instrumentation description and development, track procedure, and driver techniques. Each of the vehicles was tested for emissions following the 1975 CVS-CH Federal test procedure as specified by the Environmental Protection Agency. Included in the results are fuel economy figures for the three SAE J1082 cycles, as well as fuel economy figures obtained from the EPA dynamometer procedures. Complete vehicle specifications and emission figures are shown.

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750671. The Effect of Emission Standards and Gasoline Quality on Fuel Consumption. E. N. Cantwell, Jr., F. L. Kinnear and H. J. Russell, Petroleum Laboratory, E. I. du Pont de Nemours & Co.

The EPA urban and highway fuel economies were determined for six 1970 cars and 22 each 1974 and 1975 cars. These experimental data were combined with data from the literature to determine the effect on fuel economy of meeting past and current exhaust emission standards and to project the effect of meeting various levels of standards in the future. An average loss in fuel economy of 14% took place from 1967 to 1974 but about one-half of the loss was recovered in 1975. The requirement to meet more stringent standards in the future is projected to cause significant additional losses in fuel economy. Adoption of the emission standards recently proposed by the EPA could delay for several years the achievement of the 40% improvement in fuel economy requested of the automotive industry by the government. Imposition of the statutory standards mandated by the Clean Air Act apparently would prevent the achievement of the 40% improvement goal.

In a companion program the improvement in fuel economy as a function of the increase in octane requirement was determined for a 34-car fleet of 1970 to 1975 model cars. This information was combined with estimates by the petroleum industry of the additional energy required to increase the pool octane number to determine the optimum octane number of unleaded and leaded gasoline to minimize the consumption of crude oil. Use of the optimum octane quality unleaded gasoline of 96 Research would reduce crude usage by 2% compared with current unleaded gasoline of 91 octane number. However,

an investment of up to $20 billion would be required by the petroleum industry to increase unleaded pool octane number from current to optimum levels. Similarly, the use of the optimum octane quality leaded gasoline of 100 Research would save 2% crude oil compared with the current leaded gasolines of 95 pool octane number. However, the investment required would be much less than for unleaded gasoline. The use of leaded rather than unleaded gasoline, whether at current or optimum levels, will save 6 to 10% of the crude oil required.

750673. Energy Conservation: Optimization of the Vehicle-Fuel-Refinery System. W. T. Tierney, E. M. Johnson and N. R. Crawford, Texaco, Inc.

Studies of several options available for future vehicular transportation powerplants have strongly indicated that it is necessary to optimize the vehicle, its fuel and the refinery as a total system.

It is the purpose of this paper to report the relative miles of transportation that can be obtained from a barrel of crude oil by using different types of engines and fuels.

This concept is not new. The energy required to manufacture fuels has always been supplied by using part of the energy in the crude oil. However, the importance of the concept is compounded when one considers that large quantities of gasoline are lost due to processing requirements for producing unleaded gasoline octane numbers while concurrently, automotive emission controls and safety regulations increase gasoline consumption.

Both of these effects cause a reduced efficiency in the use of crude oil. The only true measure of the impact on energy usage caused by changes in refinery operations and vehicular modifications is to relate the miles of transportation obtained to the energy available in the crude oil. This concept accounts for both the energy needed for fuel manufacture and the energy needed to propel the vehicle.

The options that have been studied are:

1. Use of leaded gasoline in an internal combustion engine.
2. Use of unleaded gasoline.
3. Maximum use of diesel engines.
4. Maximum use of the direct injection stratified charged engine.
5. Maximum use of gas turbine engines.

It will be shown that the engine-fuel option chosen will have a large effect on the crude oil imports required which, in turn, will have a substantial impact on the United States domestic economy and balance of payments. Furthermore, the choice of the wrong option could seriously restrict the number of vehicles that could be operated if world-wide crude oil availability should become limited in supply.

Discussion: Hugh F. Shannon, Exxon Research and Engineering Co.; and J. C. Dickson, Booner and Moore.

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750674. An Historical Review of Reductions in Fuel Consumption of United States and European Engines with MoS_2. T. J. Risdon and D. A. Gresty, Climax Molybdenum Co.

The paper provides details of dynamometer, track, fleet, and leased car tests sponsored or conducted during the period 1963–1974. The data show an average improvement of 4.4% in fuel consumption results from the proper dispersion of 1% weight molybdenum disulfide (MoS_2) in the engine oil.

750675. Lubricant Viscosity Effects on Passenger Car Fuel Economy. E. D. Davison and M. L. Haviland, Research Laboratories, General Motors Corp.

As part of General Motors effort to improve fuel economy, the effects of engine and power train lubricant viscosities were investigated in passenger car tests using either high- or low-viscosity lubricants in the engine, automatic transmission, and rear axle. Fuel economy was determined in both constant speed and various driving cycle tests with the car fully warmed-up. In addition, fuel economy was determined in cold-start driving cycle tests.

Using low-viscosity lubricants instead of high-viscosity lubricants improved warmed-up fuel economy by as much as 5%, depending upon the differences in lubricant viscosity and type of driving. Cold-start fuel economy with low-viscosity lubricants was 5% greater than that with high-viscosity lubricants. With such improvements, it is concluded that significant customer fuel economy gains can be obtained by using the lowest viscosity engine and power train lubricants recommended for service. To determine if currently recommended engine oil, automatic transmission fluid, and rear axle lubricant viscosities can be reduced, extensive performance and durability testing will be required.

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750676. Lubricant Related Fuel Savings in Short Trip, Cold Weather Service. T. J. Sheahan and W. S. Romig, Lubrizol Corp.

Engine oils, gear lubricants and lubricant sets were compared on fuel economy in cold start, short trip, cold weather service using full-size and compact cars. Significant improvements in fuel economy were shown through lubricant selection. The effect of other variables was identified. Ambient temperature effects on fuel economy were quantified.

750677. Stable Colloid Additives for Engine Oils—Potential Improvement in Fuel Economy. James E. Bennington and David E. Cole, University of Michigan; Peter J. Ghirla and R. Kennedy Smith, Acheson Industries, Inc.

A series of stable colloid lubricant additives have been evaluated for their influence on vehicle fuel economy through modification of engine friction. The SAE J-1082 procedure was used to determine fuel consumption in tests conducted in a seven vehicle fleet exercise which showed

encouraging improvements in fuel economy, especially in the SAE Urban cycle. In addition, an extended dynamometer test was conducted on the most promising colloid additive system. After 100 hours of test at 55 mph (road-load), fuel consumption was reduced by approximately 2% and engine friction was inferred to have been reduced by more than 10%.

Engine oils treated with these stable colloid additives hold the promise of effecting important fuel savings over the total existing vehicle population within a minimum time frame.

750678. Critical Study of the United States Exhaust Emission Certification Test-Error and Probability Analysis. Martin Fock, Karl-Heinz Lies and Laszlo Pazsitka, Volkswagenwerk AG (Germany).

The United States regulations concerning the Automobile exhaust emissions stipulate the limits of the individual pollutants that must not be exceeded, but make no allowance for measuring uncertainties when evaluating the test results; nor are the final results subjected to any form of statistical analysis.

We have performed a critical study of the Exhaust Emission Certification Test based on statistical methods. With the results of this investigation, it is possible to calculate the real risk for passing the Certification Test and to determine the engineering goals (or safety margins) which are required to pass Certification. In addition, systematic errors should be taken into account.

Meeting these safety margins represents a calculable additional aggravation of the already stringent standards.

750679. Instrumental Practice in the CVS Method of Exhaust Emission Measurement. R. W. Hurn, Bartlesville Energy Research Center.

This paper describes recommended practices that are applicable in the CVS method of exhaust emission measurement. This method of reliable measurement has been adopted primarily because of two advantages over alternative methods: sample integrity remains unperturbed over the collective interval, and volumetric control and measurement is relatively less complicated than other procedures and the method lends itself well to direct mass measurement.

750682. Emissions Patterns of Diesel-Powered Passenger Cars. James N. Braddock and Ronald L. Bradow, United States Environmental Protection Agency.

The gaseous and particulate emissions from a light-duty diesel powered passenger car were measured by a variety of chemical analysis techniques for three different fuels, typical No. 1 and No. 2 commercial diesel fuels and the Federal Register No. 2-D smoke test fuel. Hydrocarbon emissions were found to be inversely related to fuel molecular weight. The NO_2/NO ratio was found to be much higher than for gasoline engines approaching 0.3 at low load. Particulate emissions were approximately 0.3 grams/mile for all fuels and driving cycles tested. Sulfate emissions were high, approaching that of some catalyst cars. Sulfate emissions decreased with decreasing fuel sulfur and increased by a factor of two in highway driving over urban driving. The potential pollution problems with such cars are worthy of further study.

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750683. Control of Automotive Sulfate Emissions. E. L. Holt, K. C. Bachman, W. R. Leppard and E. E. Wigg, Exxon Research and Engineering Company; and J. H. Somers, U.S. Environmental Protection Agency.

A study has been made of potential methods for controlling $SO_4^=$ emissions from oxidation catalyst-equipped vehicles. The methods considered included operating condition and catalyst changes, as well as the use of a vehicle trap for $SO_4^=$. Emissions of $SO_4^=$ from non-catalyst cars were also measured.

The only engine operating variable we found to significantly lower $SO_4^=$ emission was exhaust gas O_2 level. Limiting air pump use reduced $SO_4^=$ emissions by factors of 5 to 7 over the FTP, and by factors of 2 to more than 10 at 96 km/h. Some increase in CO and HC emissions was observed when the greatest $SO_4^=$ reductions were achieved, but it appears that properly modulated carburetion could overcome this problem. Limited excess air shows great promise as a means of minimizing $SO_4^=$ emissions. Use of a three-way or oxidation catalyst system with closed-loop fuel metering control achieved very low levels of $SO_4^=$, while simultaneously controlling CO and HC, at the stoichiometric A/F ratio and slightly leaner than stoichiometric.

Pelleted catalysts emitted lower amounts of $SO_4^=$ during low speed operation than did monoliths, because of their greater storage capacity for sulfur oxides. However, during subsequent high speed operation, the sulfur oxides were driven off, resulting in higher $SO_4^=$ emissions from pellets than from monoliths. There appears to be no clear cut overall choice between the two catalyst configurations as far as $SO_4^=$ emissions are concerned.

Catalyst age was found to be an important factor. Catalysts with 40,000 km of service gave about 65% less $SO_4^=$ emissions over the FTP, and 25–40% less at 96 km/h, compared to relatively fresh catalysts. These results show that emission inventories which are predicted from tests with relatively fresh catalysts will tend to overestimate the buildup of atmospheric sulfate from catalyst-equipped vehicles, since these cars would have an average age greater than the test vehicles.

Pt catalysts gave somewhat higher SO = emmissions than Pt-Pd catalysts, while concentration of Pt-Pd on the catalyst had no effect in the range studied. Gasoline powered vehicles without catalysts produced only negligible quantities of $SO_4=$. A Diesel powered vehicle gave higher than expected $SO_4=$ emissions, but high carbonaceous particulate emissions may have caused inaccurate

measurements.

Vehicle SO_4= traps containing CaO-based pellets achieved almost complete SO_4= removal from the exhaust for 40,000 km, but pressure drop through the trap became excessive as the sorbent swelled with age. Efforts to lower the pressure drop resulted in poor SO_4= removal and capacity. Additional work is necessary to achieve satisfactory properties for all three parameters. Suggestions for further investigation are discussed.

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750684. Performance of a Stabilized Ruthenium NO_x Reduction Catalyst. M. W. Pepper, J. A. DeLuca, R. P. Rohdes and L. S. Bernstein, Exxon Research and Engineering Co.

MgO has been found to stabilize Ru against volatilization and agglomeration under oxidizing conditions at temperatures up to 850°C (1560°F). However, before MgO stabilized Ru can be used as an automotive NO_x reduction catalyst, it must be put in a form compatible with conditions in the exhaust system. This can be done by impregnating a cordierite honeycomb, which has been washcoated first with high surface area alumina then with MgO, with Ru. Such catalysts were tested under both engine dynamometer and vehicle conditions. Good activity maintenance was found in engine dynamometer tests, but activity was lost rapidly in the vehicle tests. This rapid loss of activity was probably caused by exposure of the catalyst to surface temperatures which exceed the temperature stability limit (~900°C) of the RuO_2-MgO surface bond in current versions of this catalyst. Such temperatures could be encountered on the AMA durability cycle used in the vehicle aging of these catalysts.

750685. Army Experience with Synthetic Engine Oils in Mixed Fleet Arctic Service. S. J. Lestz, U.S. Army Fuels and Lubricants Research Laboratory; and T. C. Bowen, U.S. Army Mobility Equipment Research and Development Center.

A three-phase program was conducted by the Army in order to obtain basic data required for the development of a new arctic engine oil (OEA) specification to replace the obsolete MIL-L-10295 sub-zero engine oil specification (OES). The first phase of the program involved the development and initial testing of improved arctic engine oils formulated using synthetic hydrocarbon or ester base stock materials. The second phase of the program involved field-testing of the improved oils, and the third phase covered definition of the performance requirements necessary for the new specification, MIL-L-46167 (OEA). This paper covers the initial testing, development of the improved arctic engine oils, discussion relating to mixed fleet military field test experience with the new lubricants, and laboratory testing of these new oils in standard oil test engines as well as in a specific military high-output diesel engine. Experience has shown these new synthetic lubricants are superior to the former mineral-based oils in ground-powered equipment and that they also function well as year-round hydraulic and power transmission lubricants.

750686. Diester Synthetic Lubricants For Automotive and Diesel Applications. Ray H. Boehringer, Emery Industries, Inc.

New diester-type synthetic lubricants are being developed and tested for automotive and diesel applications. These new lubricants potentially offer fuel savings, extended oil drain intervals, longer engine life, cleaner engines, reduced down time, labor savings, easier winter starting, and faster warmup.

Standard passenger car engine sequence and extended sequence testing (SE) has been performed on the diester lubricants in an effort to substantiate long drain potential. Diesel testing has included Mack, General Motors, and Caterpillar engines. Field test data has been and is currently being generated for both passenger cars and diesels. Preliminary field data substantiates the long drain capability of synthetic lubricants based on diesters.

750687. Simulation and Evaluation of a 4-Stroke Single-Cylinder Spark Ignition Engine. M. K. Gajendra Babu and B. S. Murthy, Indian Institute of Technology (India).

This paper deals with the development and evaluation of a mathematical model for a 4-stroke, single-cylinder, spark ignition engine. This paper has two parts. The first part describes the development of the mathematical model and the computer program. The assumptions that were made in the model are also described.

The instruments that were developed for the evaluation of the model are included in the second part, which also contains the evaluation of the results obtained from the model. The simulation results are found to agree well with the experimental data.

Discussion: Rowland S. Benson, Inst. of Science and Technology, University of Manchester (U.K.); H. Heitland, VolkswagenWerk AG (West Germany); R. Mahadevan, India Pistons Ltd. (India); and R. Ramakrishnan, Ashok Leyland Ltd. (India).

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750688. On the Problem of Predicting Burning Rates in a Spark Ignition Engine. B. S. Samaga, Karnataka Regional Engineering College (India); and B. S. Murthy, Indian Institute of Technology (India).

In this paper, formulation of a mathematical model for flame propagation in a spark ignited reciprocating engine has been described. As against the common practice of assuming a laminar flame propagation model with a suitable multiplying factor for turbulence effects, a more logical approach has been adopted bringing in the concept of an engine Reynolds parameter as the criterion to determine the combustion acceleration due to turbulence. The laminar burning velocity is calculated from Semenov's thermal model for the instantaneous unburned gas condition during combustion and is augmented for engine gas turbulence through an empirical function of the

engine Reynolds parameter assuming wrinkled flame model. The turbulent flame velocity thus obtained is then corrected for flame transportation due to the expansion of the burning gases. The empirical constants in the formula have been evaluated in correlation to results of extensive experimentation on a single cylinder variable compression ratio research engine.

Discussion: K. Mahadevan, Regional Engineering College, Karnataka State (India).

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750689. Measurement of Exhaust Gas Velocity in an Internal Combustion Engine. M. K. Gajendra Babu, P. A. Janakiraman and B. S. Murthy, Indian Institute of Technology (India).

A method of measuring exhaust velocity with respect to crank angle in a 4-stroke spark ignition engine is described as is a new method of automatically selecting a crank angle in an engine under running conditions. The method of obtaining the exhaust velocity, using the selected crank angle, is also dealt with. The exhaust velocity measured for both motoring and firing conditions is included. The results provided for the firing conditions include different exhaust configurations. The cycle-to-cycle fluctuation is also provided for the above configurations.

Discussion: Rowland S. Benson and P. C. Barvah, Inst. of Science and Technology, University of Manchester (U.K.); R. Mahadevan, India Pistons Ltd. (India); and R. Ramakrishnan, Ashok Leyland Ltd. (India).

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750691. Low-Temperature Engine Oil Pumpability in Full-Scale Engines. M. L. McMillan, Research Labs., General Motors Corp., R. M. Stewart, Gulf Research and Development Co., M. F. Smith, Jr., PARAMINS Technology Div., Exxon Chemical Co.; and S. W. Rein, Texaco Inc.

ASTM Committee D-2 has undertaken a program to develop a laboratory test which correlates with low-temperature engine oil pumpability in field service. As the first step in this program, pumpability data were obtained using thirteen ASTM Pumpability Reference Oils in seven full-scale engines. The engines and oils were chosen to be representative of a wide range of commercial practice. Borderline pumping conditions, as defined by the ASTM Task Force, were determined for each oil-engine combination investigated. The mode of pumping failure in the engines and the times required to lubricate the rocker arms were also obtained.

The results indicate that substantial differences in pumpability exist among both engines and oils. Possible reasons for these differences are suggested, based on engine oil pump inlet system characteristics and the viscometric properties of the oils.

The full-scale engine pumpability data should provide the basis for the development of a laboratory bench test which will satisfactorily predict an engine oil's low-temperature pumpability characteristics in service.

Discussion: A. R. Nolf, Shell Canada.

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750692. The Influence of Polymer Additives on Journal Bearing Performance. Richard C. Rosenberg, Research Laboratories, General Motors Corp.

The temporary viscosity loss experienced by non-Newtonian lubricants, operating in a simulated engine bearing, has been determined. Included in the study were lubricant blends containing 13 commonly-used viscosity index improvers and six commercial multigraded engine oils. Bearing friction and minimum oil-film thickness data were used to determine the temporary viscosity loss. For the 13 viscosity index improvers, this temporary loss ranged from 20–96% of the polymer contributed viscosity. Results indicate that low shear rate viscosity determinations, such as the currently used ASTM D445, should not be used to characterize the behavior of these lubricants in high-speed engine bearings.

Discussion: A. Beerbower and H. Shaub, Exxon Research and Engineering Co.; and E. Bachman, Technology Div., Exxon Chemical Co.

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750693. Effect of VI improver on the In-Service Viscosity of Hydraulic Fluids. R. J. Kopko and R. L. Stambaugh, Rohm and Haas Co.

A vane pump rig of the type used in ASTM D-2882 was used to study the permanent and temporary shear loss characteristics of hydraulic fluids containing a variety of VI improvers. The influence of polymethacrylate VI improver molecular weight on performance was studied. Severity of hydraulic oil service was assessed relative to that for automotive engine oils, and the suitability of common VI improvers is discussed. It was shown that shear stable polymethacrylate VI improvers can provide a high level of performance for extended periods of time.

750694. A Method of Distributing Unleaded Gasoline. Raymond H. Klein and Walter R. Tuuri, Standard Oil Co. (Ohio).

Faced with a Federal Regulation stating that all unleaded gasoline sold after July 1, 1974 must contain no more than 0.05 grams of lead and 0.005 grams of phosphorus per gallon, a study was made to determine how to distribute unleaded gasoline from the refinery to the customer without exceeding these contamination limits. This study showed that the handling procedures normally used for unleaded gasoline were inadequate.

New handling procedures were developed and field tested. These field tests confirmed the validity of the new handling procedures which were then adopted on a company wide basis.

Analysis of an extensive number of service station samples taken each month since imposition of the regulation on July 1, 1974 have confirmed that the new method of handling unleaded gasoline has enabled this

Midwest refiner to meet the prescribed contamination limits on lead and phosphorus.

750695. Removal of Lead Contamination from Unleaded Gasoline. A. A. Zimmerman, G. S. Musser, B. J. Kraus, P. E. Godici and J. R. Siegel, Exxon Research and Engineering Co.

Various systems were developed for deleading contaminated unleaded gasoline. As shown in both laboratory and pilot plant studies, the most promising systems consisted of passing gasoline through a fixed bed of carbon or silica gel impregnated with cupric chloride. The carbon system was most effective for removal of tetraethyl lead; the silica gel system was preferred for removal of the equilibrated mix of tetraethyl and tetramethyl leads. The effect of various parameters on deleading activity is discussed. The deleading process was demonstrated to be feasible on a service station scale.

750696. Continuous Monitoring of Lead Contamination in Unleaded Gasoline. J. B. Angelo, J. R. Siegel and G. S. Musser, Exxon Research and Engineering Co.

A field test was conducted to study the feasibility of monitoring trace lead in shipments of unleaded gasoline by means of an X-ray fluorescence continuous low lead analyzer. Batches of unleaded gasoline were blended at the refinery and transported to distant terminals by tankers and by pipeline. The low lead analyzer was used to continuously monitor the lead content of the unleaded gasoline as it left the refinery and was received at the terminals. Field data of good precision were in agreement with the accepted ASTM D-3237 atomic absorption method. The standard deviation of the X-ray method is ± 0.0029 g Pb/gal and the test repeatability is ± 0.008 g Pb/gal. X-ray fluorescence appears to be the best practical method available to determine the average level of lead contamination in large volumes of unleaded gasoline in the field with accuracy and precision.

750697. Exhaust Sulfur Oxide Measurement Using Air Dilution. M. E. Griffing, L. F. Gilbert, G. Ter Haar, P. A. Immethun and D. W. Zutaut, Ethyl Corporation.

This paper describes a method for accurately measuring sulfur oxides in automotive exhaust. In this method, the exhaust from a car is diluted with ambient air, then introduced into a large bag filled with clean dry air. The temperature, pressure, and humidity of the diluted exhaust are measured, along with the concentrations of hydrocarbons, carbon monoxide, carbon dioxide, SO_2, and sulfates. Bag concentrations are related to the exhaust by using the sulfur/carbon ratio of the fuel. Established instrumental methods are used for the carbon compounds. The sulfur dioxide in the diluted exhaust gas is measured by the West-Gaeke method, which involves collecting a gaseous sample in a scrubber containing potassium tetrachloromercurate. The sulfates are collected on a particulate filter and measured by a new colorimetric method.

The techniques we have developed have been applied to both non-catalyst and catalyst-equipped cars. These studies have shown that:

1. Non-catalyst cars emit very low sulfates (less than 1% of fuel sulfur). This conclusion applies to non-catalyst production cars burning unleaded fuel, leaded fuel, or fuel containing manganese, and also to prototype cars equipped with advanced emission systems (for example, Ethyl's Lean Reactor car and cars equipped with Ethyl's Turbulent Flow System).

2. Under some driving conditions, monolithic catalysts convert a major portion of the fuel sulfur to sulfates at concentrations close to thermodynamic equilibrium. At 40 mph, as high as 86% of the fuel sulfur was emitted as sulfates in one 1975 car.

3. Monolithic catalysts can store significant amounts of sulfates, and this storage seems to be temperature related.

4. Driving on a durability route discharges sulfur from the catalyst bed. Thus, low sulfate emissions are found for the next 150 miles or so while the catalyst again stores sulfates.

Discussion: L. S. Bernstein, Exxon Research and Engineering Co.; and Joe Somers, U.S. Environmental Protection Agency.

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750698. Lean Combustion of Methanol-Gasoline Blends in a Single Cylinder SI Engine. Edward J. Canton, S. S. Lestz and W. E. Meyer, Pennsylvania State University.

Blends of up to 40% by volume methanol in a methanol-gasoline fuel blend were supplied to a single cylinder engine operating under controlled conditions. The following effects are reported as the methanol concentration increases. The lean misfire limit is extended 0.04 Ø by using a blend containing 40% methanol compared to the base fuel. It is also noted that the lean misfire limit does not vary until a blend containing greater than 20% methanol was used. Torque and thermal efficiency increase significantly. Percent by volume concentrations of carbon monoxide, carbon dioxide and oxides of nitrogen do not change, although oxides of nitrogen reported as mass per power output per hour decrease.

750701. Criteria for Choosing and Evaluating Aerodynamic Devices for Reducing Fuel Consumption of Trucks. Paul T. Bauer and Ronald A. Servais, Creative Engineering Consultants and Associates.

A general approach to the decision to use an aerodynamic device is outlined with the objective to increase profits within the framework of a corporate priority system. Many factors affect this economic decision. The process by which the decision is reached involves both a vehicle and an economic model. Three major considerations are: a) the aerodynamic performance of a proposed device, especially with significant cross winds, b) the structural

characteristics of the device with regard to failure model, and the impact of the device of tractor or trailer body, and c) whether the device is tractor or trailer mounted.

It is noted that the attachment of a device is generally associated with a change in the equilibrium operating speed where the power required equals the power available. This change can significantly reduce the potential fuel savings to an impractical level, especially if the device has a poor cross wind behavior. The difficulty of conducting reliable fleet tests is discussed. Such tests can be very time-consuming while resulting in uncertain conclusions. It is recommended that a controlled test used combined with a realistic appraisal of changes to be expected in fleet operation.

750702. Development of Devices to Reduce the Aerodynamic Resistance of Trucks. P. B. S. Lissaman, AeroVironment Inc.

A summary of AeroVironment Inc. research programs in Truck Drag Reduction is given. These programs involve analytical studies, wind tunnel testing, full-scale field tests, full-scale road test, and operational testing. A number of different test methods and instrumentation techniques have been perfected which operate simply and reliably, and give precision of higher than 2% under windless conditions.

A discussion of the basic elements of bluff body drag, as it relates to truck air resistance is given. The concept of a dragless forebody is introduced. It is shown that this dragless state can nearly be achieved with a lip-like device on the front face of the van. The shielding effect of one body ahead of another is described, and the deleterious effects of crossflow in the gap between the bodies is discussed. In particular, it is shown that some add-on devices are particularly susceptible to crosswind flows and lose effectiveness at a few degrees of yaw.

Two devices, one, the lip, for the front face of the van body, and the other, the perforated screen for tractor mounting, are described, with their principles of operation. These devices have been road tested and give very substantial savings in aerodynamic drag coefficients, exceeding 30% in both cases. The fuel savings associated with such devices depend upon payload, speed, etc., but can be as much as 60% of the aerodynamic drag saving.

The importance of full-scale testing under operational conditions is pointed out with particular reference to random wind effect. It is noted that the devices described appear to function well under crosswind conditions.

750703. Aerodynamic Drag Reduction Tests on a Full-Scale Tractor-Trailer Combination and a Representative Box-Shaped Ground Vehicle. Louis L. Steers, Lawrence C. Montoya and Edwin J. Saltzman, NASA Flight Research Center.

Aerodynamic drag tests were performed on a tractor-trailer combination and a box-shaped ground vehicle using the coast-down method on a smooth, nearly level runway. The tractor-trailer tests included an investigation of drag reduction add-on devices that are commercially available or under development. The box-shaped vehicle was modified by rounding the corners and sealing the undercarriage. The tests ranged in velocity from approximately 35 miles per hour to 65 miles per hour for the tractor-trailer combination and included fuel consumption measurements and one set of measurements of drive shaft torque. This paper presents the results for both vehicles, showing the effects of the various modifications on the aerodynamic drag. The effects of variation in the aerodynamic drag of the tractor-trailer combination on fuel consumption are also presented.

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750704. Comparisons of Effectiveness of Commercially Available Devices for the Reduction of Aerodynamic Drag on Tractor-Trailers. Frank T. Buckley, Jr., Dept. of Mechanical Engineering, University of Maryland; and William S. Sekscienski, Wind Tunnel Operations Dept., University of Maryland.

Wind tunnel experiments, with emphasis on cross-wind effects, have been used to evaluate the effectiveness of a number of commercially available devices for reducing the aerodynamic drag of a tractor-trailer combination. The evaluations included consideration of the effects of tractor type, trailer height, and the bluffness of the tractors and/or trailers. A wind-averaged drag coefficient was introduced to interpret the basic data for the prediction of average drag in a highway environment. The average drag of the base-line vehicles was found to be a strong function of the bluffness of the tractor and/or trailer, and a weak function of the tractor type. Estimates of the average fuel savings that would result from the application of the various drag reducing devices ranged from -400 to 3300 gallons per 100,000 miles, depending on the combination of tractor, trailer and device that is used.

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750705. Wind Tunnel Development of the Dragfoiler—A System for Reducing Tractor-Trailer Aerodynamic Drag. William T. Mason, Jr., Research Laboratories, General Motors Corp.

Dragfoiler II, an effective and practical add-on aerodynamic drag reducing system for tractor-trailers, has been developed. Wind tunnel tests with 1/16- and 1/7-scale tractor-trailer models were used to determine empirical design guidelines for the Dragfoiler II's side elevation and planform shapes. Optimum designs for various combinations of tractor roof height and length, trailer height, and tractor-to-trailer gap length gave zero-yaw drag reductions between 30 and 35%. At a yaw angle of 10 deg, the percentage drag reductions were about half those at 0 deg. Off-design performance and the effects of trailer side-edge geometry were investigated. Several full-scale Dragfoiler II's are currently undergoing

proving ground and commercial fleet evaluation tests.

Discussion: J. C. Firey, Dept. of Mechanical Engineering, University of Washington.

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750707. Aerodynamic Devices Can Significantly Reduce the Fuel Consumption of Trucks: Experience with CECA Designs. Ronald A. Servais and Paul T. Bauer, Creative Engineering Consultants and Associates.

An economic study relating aerodynamic performance to fuel consumption has been completed. An experimental windtunnel evaluation of both new shapes and modified shapes for semi-tractors has been conducted and the results show that it is possible to both modify existing tractors and design new tractors which will result in substantial fuel savings. The windtunnel tests included collecting force and moment data at various yaw angles on several tractor-trailer combinations, including cabovers and conventional tractors, a variety of streamlining modifications to those tractors, plus some entirely new tractor shapes. A method for incorporating the modifications on existing tractors has been road tested and the results are discussed.

750708. Computer Prediction of Power and Noise for Two-Stroke Engines with Power Tuned, Silenced Exhausts. D. C. Karnopp, H. A. Dwyer and D. L. Margolis, Mechanical Engineering Dept., University of California.

A research effort sponsored by Yamaha Motors, Ltd. was undertaken to investigate exhaust system and exhaust silencing concepts for two-stroke engines. A complete one-dimensional gas dynamic computer program was developed for power-tuned exhaust systems. This program provides great insight into the actual nonlinear wave behavior of both conventional and innovative power-tuned exhaust systems. In addition, the simulated outlet flow rate has been coupled with the spherical wave equation in order to predict sound levels at any distance from the engine.

An overall engine model has been developed for simulation of the internal gas dynamic behavior throughout the engine. This model includes the combustion and induction aspects of the engine cycle as well as a simplified exhaust system model. Engine power and torque can be predicted. The main use of the engine model is in comparative studies of engine parameter variations.

Finally, both analytical and experimental programs are described for simulation and testing of candidate mufflers and muffling techniques. Since it is desirable to avoid using absorptive material in the exhaust systems of oil burning engines, reactive mufflers were studied primarily. The simplest analytical approach consisted of using the flow output of the complete exhaust system model as an input to linearized acoustic filter models, neglecting all "back" effects of the filter. Using the simple source equation, sound levels from the acoustic filters can be predicted. The accuracy of this procedure is not good but is quite useful for comparative studies.

A second approach includes the "back" effect of the muffler on the exhaust system. This is accomplished by coupling the gas dynamic equations to the muffler equations and solving simultaneously. Although accuracy is improved, the relatively expensive gas dynamic program must be run for each muffler configuration tested.

One-dimensional nonlinear reactive mufflers were incorporated directly into the gas dynamic program. The results showed that acoustic circuit analysis was often optimistic in noise attenuation prediction.

750714. Marine Propulsion Gas Turbines—Towards the Establishment of Defined Niches and Other Trends. David A. O'Neil, Seaworthy Engine Systems.

In the last four of the past twenty-eight year history of marine propulsion gas turbine engines, their numbers have doubled. Specific types of gas turbine engines in certain areas of compatibility with both military and commercial vessel power plant design have become recognized as being well beyond the prototype stage. The appearance of the establishment of some application trends and niches is described and rationalized from the technical and historical/statistical viewpoints. Demonstrated Engineering, Economic and Operational advantages are presented with emphasis in the large commercial marine services.

750715. New Developments in Marine Propulsion Controls. Harold M. Mathers and Dennis J. Kammeyer, Mathers Controls, Inc.

Proper control of governor, clutch and propeller shaft brakes can minimize engine, gear and clutch loading, and aid in preventing engine stalling. The requirement is particularly apparent in the high output diesel engines of 500 to 10,000 horsepower with turbo-charging and aftercooling.

750716. SS MAINE Roll-On Roll-Off Concept. P. S. Mead, States Steamship Co.

This paper deals with States Steamship Company's new Roll-On/Roll-Off (RO/RO) ship, the SS MAINE. It examines four particular aspects: the concept of the RO/RO ship, the physical aspects of the ship, the cargo equipment, and cargo handling contingencies. By examining other RO/RO vessels, they were able to develop their own concept of the RO/RO ship.

750717. Construction of the Polar Star: A Shipyard View. William R. Nodell, Lockheed Shipbuilding and Construction Co.

This paper summarizes the characteristics and layout of the new U.S. Polar Icebreaker and highlights some of the fabrication problems encountered by the shipyard during the construction. The author deals briefly with the types of steel used, the difficulties of welding due to the types and

thicknesses of steel and the abnormal amounts of non-destructive testing used to prove the product free from defects in construction. The machinery selection is discussed including the controls, the versatility of component operation, and the layout. The unusual preparations for launching are discussed including some statistical data from the launch.

750718. A Chronology and Development Status of the Amphibious Assault Landing Craft JEFF(A). James H. Seely, AALC Operations, Aerojet Energy Conversion Co.

The Amphibious Assault Landing Craft (AALC), currently being developed by the U.S. Navy for Marine Corp. use, is a high performance air cushion vehicle (ACV) specifically designed to the requirements of a unique advanced landing craft system. Initially conceived in the mid-1960s, one of two preliminary design contracts was awarded to the Aerojet-General Corporation in January, 1970, followed in March of 1971 by a contract for the design, construction and test of a developmental prototype designated the JEFF(A).

This paper presents a discussion of major program events leading to the present state of construction of the JEFF(A), followed by a design description of the craft and major subsystems, including unique design criteria. Additionally, the present state of construction including illustrations of major subsystems is given. Finally, a discussion is presented of the events planned from the present time through completion of Navy trials.

750719. Boeing JETFOIL. William M. Shultz, Boeing Aerospace Co.

The JETFOIL is an advanced design hydrofoil that employs fully submerged foils, automatic stabilization and control, and gas turbine powered waterjet propulsion to achieve high speed, rough sea operations. Introduction into regular passenger services during 1975 followed 7 months of extensive underway builders trials. Configuration details are provided and the results of the performance, seastate and certification trials are discussed.

750720. Protecting the Operator From the Hostile Environment of Woods Operation. Robert Rathe, John Deere Dubuque Works.

Logging safety is discussed in terms of recognition of hazards and their elimination. The conclusions drawn from NIOSH study of logging safety is that the creation of work practice regulations and the encapsulation of the operator on a machine will reduce logging accidents.

Standards that apply to forestry equipment design are listed and examples of how one company is approaching the problem of providing a machine which will satisfy the safety requirements are detailed.

750721. Total Environment Engineering—The Challenge. J. Gerald Smith, Eaton Yale Ltd., div., Eaton Corp.

This paper is an attempt to pull together, under the concept of "total environment", some concerns and philosophies associated with such subjects as product application, product maintenance, human, ecological, economic and legal considerations. It is intended to emphasize the need for real understanding of these subjects, to stimulate the thinking of engineers, manufacturers and end users, and to demonstrate the effect their performance can have on many aspects of our society.

750722. A Tree Harvesting Attachment for Felling and Bunching. Frank J. Tucek, Drott Manufacturing Div., J. I. Case.

A logging attachment for felling and bunching full trees has been developed and is now being utilized for mechanized harvesting. The attachment allows an operator full control to sever, position, and lay trees into desired bunches so they can be easily skidded out of the forest for loading and transport.

Many requirements must be considered to develop such an attachment. It must efficiently sever various types and sizes of trees. It must also effectively handle these varying tree diameters, heights, and weights. The attachment must withstand accumulations of ice and debris. The structure must withstand rough usage in typical harvesting conditions which expose it to snow, mud, rocks, undergrowth, and stumps.

750723. Excavating Tar Sands in Canada. Thomas I. Harrison, WABCO.

This paper discusses the history of the Athabasca Oil Sands in Alberta, Canada, from the time of their discovery in 1788 to the present. These oil sands extend over 30,000 square miles and are equal to half of the world's known "conventional" oil accumulations. Besides the history of the oil sands, the paper discusses the known processes available for excavation here, the problems faced because of the extreme cold weather (for example, what kind of fuels, lubricants, even vehicles themselves should be used?), and offers suggestions for successful cold weather operations.

750724. Mining Oil Shale. Robert B. Crookston, Oil Shale Corp.

Mining oil shale in Colorado for the first commercial oil shale venture has been optimized by Colony in terms of the best mining method and equipment available today. A discussion of the progress toward optimization of mining by Colony and others and of the nature and extent of oil shale in Colorado and Utah leads into a recitation of the potential for improvements.

Some of the problems of the "yet to be" oil shale industry, with a look at yesterday, the status and activity of the industry today and the promise of tomorrow, provide useful information for the uninitiated.

750726. An Over-the-Road Fuel Economy Test. Alexander Carr, Carr Engineering.

This paper discusses an over-the-road fuel economy test procedure developed to show a true reflection of fuel consumption for the everyday road user. It explains the parameters for the test, the preparation involved, the test procedures, and an analysis of the tests.

750727. The Office of Technology Assessment: Overview and Materials Programs. John B. Wachtman, Jr., Office of Technology Assessment.

The newly-established Office of Technology Assessment of the United States Congress has assessment programs on energy, food, health, materials, oceans, technology and world trade, transportation, and exploratory assessments. All programs were developed in response to Congressional requests. The Materials Program consists of assessments on Materials Information Systems, National Stockpile Policy, Resource Recovery, Materials Recycling and Reuse, Institutional Factors in Domestic Minerals Accessibility, and Materials Conservation Through Reduced Wastage.

750729. Design and Development of the Caterpillar 7155 Semi-Automatic Heavy-Duty Truck Transmission. Philip S. Webber and Harry B. Newman, Caterpillar Tractor Co.

The heavy-duty truck industry has seen the need for a change in the concept of transmission design for many years. Several improvements have been made and others attempted, but greater improvement is needed to match the engine's delivery to the vehicle's demand. Driver performance can be improved and fatigue reduced by lowering the effort and skill required to make smooth, consistent starts and ratio changes. This paper discusses a solution to this need in the design and development of a semi-automatic, pneumatically controlled, constant mesh transmission.

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750730. An Automatic Transmission In Line Haul Vehicles After Two Years of Fleet Evaluation. E. R. Cottingham, Detroit Diesel Allison Div., General Motors Corp.

Automatic transmissions in line haul vehicles had been practically non-existent until the Allison HT750-CRD model was specifically designed for that vocation. Prior to the start of production of this new automatic, a comprehensive market survey was conducted to determine line haul carrier interest in the automatic as a solution to manual transmission related problems. As a result of the survey, an extensive Fleet Evaluation Program was initiated to firmly establish product acceptance, product durability, and cost comparisons with manual-equipped units. The program was designed to cover a broad range of vehicle duty cycles and vehicle and engine makes.

The findings of more than two years of fleet testing are discussed, along with the initial design of the transmission and its controls and transmission refinements and installation improvements derived from the program.

750731. The Snapper, Design and Development of a Self-Engaging Mechanical Transmission. Edward J. Bogema and John R. Vandervoort, Transmission Div., Eaton Corp.

A new concept of a mechanical transmission has been developed using engine synchronization and frictional blockers to control engagement. A history of this development is herein given from the earliest concept to the present state as well as a projection of future possibilities.

This approach is directed toward fulfilling the requirements that have caused an interest in heavy-duty automatic transmissions for trucks and does this with little penalty in expense or complexity.

750732. Application Considerations with the Cummins Sundstrand DMT-25 Hydromechanical Transmission. Paul E. Troin, Cummins Sundstrand, Inc.; and Vic G. Gostomski, Hydro-Transmission Div., Sundstrand Corp.

A fully automatic hydromechanical transmission has been successfully applied in a variety of heavy duty trucks and is now being offered by numerous truck manufacturers. Significant differences in application and installation technique exist between a hydromechanical transmission and fixed ratio truck transmissions. This paper discusses major application and installation considerations with the hydromechanical transmission and also suggests new approaches for engine/transmission package optimization, governor control interface improvements, and increased vehicle productivity.

750733. Effects of Disk Material Selection on Disk Brake Rotor Configuration. Jack D. Rainbolt, B. F. Goodrich Engineered Systems Co.

Due to the recent requirements of FMVSS-121 for improvements in heavy vehicle braking capabilities, the high torque caliper type disk brake is emerging as the "superior brake". Caliper disk brakes not only possess high linear torque capabilities but also excellent directional stability wheel to wheel. However, the high torque capabilities result in high energy input to the disk. This high energy produces premature failure in the traditionally used cast iron ventilated disk in the form of "temperature induced cracking". This paper will discuss the thermal mechanisms that produce "disk cracking" and how disk material selection affects the disk configuration.

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750734. Air Wedge Disc Brakes for Heavy Truck Front Axles. Bruce D. Anderson, Rockwell International.

The general vehicle application, design criteria and part description of the Rockwell air-wedge actuated disc brake combined with laboratory dynamometer and test truck evaluation support the feasibility and desirability of

applying air actuated disc brakes to front axles of heavy trucks and tractors.

750735. Transbus—Testing and Public Evaluation (Around the Country in 80 Days). Joe F. Atkins, Rohr Industries, Inc.

This paper describes the test and evaluation phases of the Rohr Transbus program which was initiated by the Department of Transportation in 1972.

Vehicle testing was conducted both by Rohr Industries and by the prime contractor, Booz-Allen Applied Research. This report details the scope of this effort made to analyze the integrity and other qualities of these new buses.

An extensive program was conducted to evaluate the public and transit authority acceptance of the new designs incorporated in the Transbuses. This paper describes this program and details some basic information gathered as a result of this evaluation.

750736. The Design of a Steam Powered Paratransit Vehicle. David D. Norton, Steam Power Systems, Inc.

The design of a new concept in urban transportation, the steam powered paratransit vehicle (PTV), is described. The vehicle incorporates the following features: an external combustion engine (ECE) power system, a unique aluminum chassis and body structure whose primary elements are bonded honeycomb sandwich panels, an automatic passenger door and loading ramp system capable of accommodating a wheel chair seated passenger without assistance, a roof-mounted condenser system, an all-independent suspension system incorporating torsion bar springs and self-leveling shock absorbers, and a near-center driver's station isolated from passengers by a bullet resistant partition. The steam PTV is expected to satisfy the maximum emissions levels prescribed by the 1977–78 Federal Standards, operating on a wide variety of petroleum and non-petroleum fuels, with fuel mileage comparable to existing taxicabs.

750746. Formed-in-Place Gasketing With Silicones. J. R. Hilliard, Technical Service and Development, Dow Corning Corp.

Formed-in-place gasketing is a versatile concept, which offers cost reduction and improved sealing performance in small engines. Easily automated, the process can lower both material and labor costs in high volume production.

The concept itself is simple. A paste-consistency silicone rubber is applied to the flange area of the parts to be sealed. The parts are then assembled, and the silicone paste is squeezed into every area to fill large or small gaps between the mating surfaces as the parts are drawn together. The paste then cures to form a durable rubber seal which is stable from -100° to 450° F.

750747. High Energy C.D. Ignition with Surface Gap Spark Plugs for Improved Ignition in Two-Cycle Engines. Richard B. Zentmeyer, Jr. and Elwin J. Brayley, Prestolite Electrical Div., ELTRA Corp.

A High Energy C.D. Ignition system has been developed that is capable of operating surface gap spark plugs with excellent results. Surface gap spark plugs have existed in various forms for many years, and ignition systems of various forms have been developed, attempting to fire them, using both Inductive Discharge and Capacitive Discharge types of ignition. It has been shown that an Inductive Discharge spark with its low peak spark current and slow voltage risetime will not operate a surface gap spark plug. A high energy C.D. spark, with its rapid release of power and fast voltage risetime is necessary to keep a surface gap plug clean for extended periods. The first application for this ignition system has been on snowmobile engines.

750748. Small Engine Carburetors—State-of-the-Art. John C. Woody, Marvel-Schebler/Tillotson Div.

There are basically three types of carburetors commonly used on small gasoline engines. The correct selection of the basic carburetor type depends on the end use of the engine-carburetor package. Since the initial selection of carburetor type is often made in the design stage of the package, a basic approach to carburetor type selection is presented.

The areas of current engineering emphasis are improved performance and lower manufacturing costs. These are now possible due to recent methods of carburetor construction.

750751. Air Intake Silencing for Small Engines. Ian N. Swanson, Donaldson Co., Inc.

Intake silencing on small engines can be used to improve power output as well as reduce sound levels. The parameters involved are intricate and only partially understood. Two approaches to silencing and power retention are outlined in this paper.

750752. Studying Scavenge Flow in a Two-Stroke Cycle Engine. G. P. Blair, Ashby Institute, Queen's University of Belfast (Northern Ireland).

The study of scavenge flow in two-cycle engines is of great importance in the development of that type of internal combustion engine and has been extensively covered by numerous researchers over the last half-century. Alfred Jante in SAE paper 680468 suggested an indirect and comparative test for the assessment of scavenge flow which he, and others, have shown to be both a simple and extremely relevant technique. The acquisition and reduction of data for this experimental method proved to be laborious and time consuming, and it is the purpose of this paper to show that it is possible to eliminate these tedious aspects by automation of both data recording and processing. This is described and examples of its usage are given.

750753. The Evolution of Sound Testing at Kohler Co. Richard A. Dykstra, Kohler Co.

The purpose of this paper is to discuss the development of Kohler Company's Small-Engine Noise Test Program. Particular emphasis will be placed on noise instrumentation and analysis techniques. The paper will not dwell on the specifics of each noise study technique, but will be an overview, describing the evolution of Kohler's Noise Test Program in general.

750754. Is Metrication Rated "PG" or "R". G. Stewart Johnson, Dept. of Mechanical Engineering, Western Michigan University.

There seems to be a general consensus prevailing in the engineering community that conversion to S.I. metric units of measure poses no problems. If charts showing metric equivalents are evaluated, this appears to be the case. However, as Metrication is analyzed from the viewpoint of thinking in metrics and performing calculations entirely in metrics, various standards, procedures, and techniques must be followed. For this reason, familiarity with metric units is gained by associating them with physical sizes and quantities plus making everyday calculations in S.I. metric units.

750758. Dynamic Method for Storage Battery Diagnostic Testing. Keith S. Champlin, Electrical Engineering Dept., University of Minnesota.

Electrical techniques for field testing storage batteries have been traditionally based upon measuring static voltage. Examples include measurements of:

(1) Open circuit cell and terminal voltage;

(2) Terminal voltage during "discharge-charge" cycling—the so-called "421 test";

(3) Terminal voltage during high rate discharge—the common "load test".

Although each of these techniques has specific advantages, the load test has unquestionably been the most widely employed. Its utility is limited, however, by the large currents required. Apparatus to handle such currents is relatively heavy and cumbersome. Furthermore, a typical test consumes appreciable time and severely polarizes the battery. As a consequence of the latter, load test voltages are not repeatable.

This paper describes an alternate testing technique that correlates well with the load test but does not suffer these disadvantages. Instead of measuring static voltage, the battery's dynamic conductance is sensed electronically using a time varying signal. This quantity is proportional to the maximum power available and provides a direct measure of the battery's overall condition. Since large currents are not required, the testing apparatus can be small and lightweight. Moreover, dynamic measurements are instantaneous, uneffected by polarization, and can be routinely performed without perturbing the battery.

The dynamic measuring technique is embodied in the electronic battery tester described herein. This device provides either an absolute determination of maximum power (in KW) available at the battery terminals, or a "pass-fail" assessment based on the battery's rating and temperature. Comparisons are made between dynamic and load test measurements at both 70°F and 0°F, and a high degree of correlation is observed. The effects of battery size, temperature, charge, and polarization are discussed. Specific uses of the dynamic measuring technique are proposed which take advantage of its inherent reproducibility, accuracy, and facility.

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750761. Energy Economics of Automotive Power Generation. W. Tipler, Perkins Engines Co. (United Kingdom).

This paper aims to demonstrate the importance of considering fuel production and utilisation as inter-related components of a single process—the conversion of natural chemical energy into a usable form in an economic manner.

Taking automotive power generation as an example it is shown that this integrated approach can result in appreciable reductions in the rate of consumption of crude oil. If the alternative of producing automotive fuels from coal (using known technology) is examined, it becomes apparent that both the gasoline engine and diesel engine should be replaced by the spark assisted diesel engine in the interests of energy economy.

750762. Direct Utilization of Crude Oil as a Fuel For High-Speed Diesel Engines. E. C. Owens and E. A. Frame, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute; and Walter Bryzik, U.S. Army Tank Automotive Command.

Crude oils with a wide range of properties were investigated for direct use as fuel in U.S. Army high-speed four-cycle diesel engines. Crude oil properties were divided into two groups: 1. those properties which would be of importance for short-term operational effects, and 2. those properties whose effects would manifest during longer-term operation. Effects of crude oil use on engine subsystem hardware such as fuel filters and fuel injection pumps were investigated. Performance and combustion data were determined using pre-cup and direct injection configurations of the single cylinder CLR diesel engine operating on various crude oils. Performance data, wear and deposition effects of crude oil use were obtained using the TACOM single cylinder diesel engine. Results of this investigation showed that a wide range of crude oils with proper selection and pretreatment are feasible emergency energy sources for U.S. Army four-cycle high-speed diesel engines.

750763. Methanol/Gasoline Blends as Automotive Fuel. J. R. Allsup, Bartlesville Energy Research Center.

An experimental program was conducted by the Energy Research & Development Administration's Bartlesville

(Okla.) Energy Research Center to determine the effect on exhaust emissions and fuel economy when methanol is added to conventional motor fuel, that is, gasoline. Ten 1974 and 1975 model vehicles were used in the study. Ambient temperature was varied from 20° to 100°F to determine temperature effects while using methanol/gasoline blends. Emissions were generally modified as a consequence of the fact that the addition of methanol to gasoline alters both the fuel vapor pressure and the stoichiometry of the air-fuel mixture. Fuel economy was generally decreased by methanol addition.

Moderate mileage accumulation using 10% methanol fuel showed no deterioration either in emissions control or of fuel-related engine components. Driveability differences between methanol 10% blends and gasoline were detectable but were judged not to be objectionable.

750765. Automatic and Adaptive Controls for Construction Equipment. Carter J. Ward, Civil Engineering Laboratory, Naval Construction Battalion Center.

Automatic/adaptive controls for large earthmoving equipment have been developed, and have proven to be effective in improving the performance of these machines while reducing the skill required of the operators. These controls speed up earthmoving tasks, make it easier for the machines to work at night, and contribute to lower construction costs. Controls suitable for motor graders, scrapers and bulldozers have been demonstrated.

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750766. Remote Control Bobcat Loader. Gilbert E. Redzinski and G. A. Morrell, Central Development Div., Clark Equipment Co.

The Melroe M-700 BOBCAT is a small capacity, rigid-frame, skid-steer front end loader. Two independent hydrostatic transmissions propel and steer the loader. A separate hydraulic system controls all the motions of the loader's boom and bucket. It is an extremely versatile vehicle, and is potentially useful in some environments hostile to humans. To accommodate these applications, a remote control system was designed and installed on a vehicle. This system allows the operator complete control of the vehicle from a remote location. Control line between the operator and vehicle is a multi-wire electrical cable. Major objectives accomplished were:

1. Remote control system installation with minimum modification to the basic vehicle.

2. Minimum changeover when switching between remote and on-board control.

. Dead man concept in remote operation that is, hands off of controls returns all systems to off or stop condition.

750767. Optimizing Hydrostatic Transmission Controls for Garden Tractors. Roger D. Mayhew, Outdoor Power Equipment Div., FMC Corp.

The use of hydrostatic transmissions in garden tractors started about 10 years ago. The control systems for hydrostatic transmissions have evolved from a simple hand held lever to a foot actuated pedal controlling a direct linkage system with acceleration valves that is interlocked with the brakes, attachment drive, and engine starter.

750768. Performance Simulation of a Diesel Piston and Ring System. G. R. Bishop and A. H. Leavitt, John Deere Waterloo Product Engineering.

Analytical models of piston movement, gas flow in the ring belt, and piston ring movement are described and integrated to form a system simulation which was implemented on a digital computer. Sample computer solutions are given to illustrate the models' usefulness in predicting the effect of design and operating variables upon specific performance characteristics. Suggested refinements to the system model are also discussed.

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750769. New Developments in Piston Rings for the Modern Diesel Engine. H. E. McCormick, R. D. Anderson, D. J. Mayhew and W. J. Rychlewski, T.R.W. Piston Ring Div. T.R.W. Inc.

This paper presents unpublished data on new coating developments, new piston ring designs, and design considerations for the modern diesel engine. Data on the current state-of-the-art of compression ring coatings along with technical data on new generation coatings are included as well as data on ring designs and/or design considerations which may be used to improve engine performance and life with respect to blow-by and oil control.

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750770. Small Bore Diesel Engine Testing Using the Fractional Factorial Technique to Evaluate Oil Control. Paul R. Shepler, Edward F. Willem and Erwin C. Brunke, Koppers Co. Inc.

Piston - ring - liner combinations have been identified that will reduce oil consumptions to less than 1/4 of the consumption for small-bore diesel engines as received. This is based on 31 test series from 1966 to date wherein a factorial plan has been used. In the 31 series some of the potential factors have been studied many times and the resulting data have been compiled into a group of summary tables and these tables are presented. Some factors are specific to each engine and some are general to all engines. The need to have proper pistons and proper liners to make piston rings work are discussed.

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750771. Field Test Experience with New Electronic Governor. E. L. Whitford, Precision Dynamics Div., Barber-Colman Co.

A new all-electric governor system has been developed for application to a wide range of rotating machinery. This

new governor has application potential to any system requiring precise speed control or automatically variable speed control, including electrical generating equipment. This new governor consists of a linear proportional solenoid controlled with large-scale integrated circuits packaged for direct mounting on the engine.

This paper reports the field test experience encountered with this governor during the first two years of its development.

750772. New Methods for Reducing Visible Emissions of Diesel Engines. G. Fraenkle and H. O. Hardenberg, Daimler-Benz AG (Germany).

From engine test results, methods can be derived for reducing visible emissions of diesel engines, particularly under such operating conditions which so far are not yet subject to environment protection legislation.

It is general practice today when starting diesel engines to inject excess fuel, that is, an additional amount of fuel in excess of the full load quantity, independent of ambient and engine temperatures and regardless of whether this is necessary or not. It is demonstrated that excess fuel should only be injected when starting a cold engine at ambient temperatures below freezing point and that the quantity of excess fuel should increase with falling temperature, reaching its maximum at the minimum engine starting temperature. The excess fuel quantity injected can be controlled with the aid of a wax element, so that, when the engine is warm, only the full load fuel quantity is injected. This eliminates the well-known cloud of black smoke emitted when starting a warm engine and considerably improves smoke emission when accelerating at low engine speeds.

A burner starting aid of simple design and fully automatic operation is described, which has been newly developed and is used to suppress, or even to eliminate, the emission of white and blue smoke during cold start and warm-up.

750773. Characterization and Simulation of a Unit Injector. N. A. Henein, T. Singh and J. Rozanski, Wayne State University.

The characteristics of the diesel engine unit injector were studied both theoretically and experimentally. The transient fuel pressure in the unit injector was indirectly measured by using strain gauges placed in different locations on the drive train, between the cam and plunger. The events which take place during the injection process were analyzed and the effects of several design and operating variables on the different injection parameters were determined. Computer simulation showed a fairly good agreement between computed and experimental results.

750774. A New Diesel Injection Pump with High Injection Rate, Its Influence on Smoke and Emissions. V. Montanari, A. Antonucci, P. F. Rivolo and C. Lombardi, Fiat, S.p.A. (Italy).

This report discusses some problems connected with the reduction of exhaust emissions and fuel consumption for direct injection Diesel engines; it indicates how they may be solved without modifying the basic power unit. The study was made on a standard production engine used in European heavy duty trucks. The effect of a number of individual variables was studied, including injection timing, injection rate, exhaust gas treatment (catalytic exhaust system), intake air pressure (including supercharging), charge dilution with exhaust gas recirculation, etc. After this first series of tests had been made, the effect of a combination of these variables was examined. To obtain the optimum results with a system providing a very fast injection rate, the effect of changes in the degree of turbulence was evaluated.

The results of the study demonstrate that the use of a pump which is able to provide very high injection rates enables an engine to operate with low values of NO_2 + HC with only marginal losses in power and fuel consumption, and at the same smoke level. The second part of the paper gives details of the FIAT DRF experimental injection pump which provided the very high injection rates needed for this programme.

750775. Shaping Sound Frequency Spectra of Axial Flow Fans. Kent C. Bates, Caterpillar Tractor Co.; and Roger R. Yoerger, Agricultural Engineering Dept., University of Illinois.

An analytical description of the sound pressure radiated aerodynamically by axial flow engine cooling fans is developed using semiempirical methods. Mathematical manipulation and digital computer techniques are employed to yield complete time and frequency sound pressure spectrums and overall sound pressure levels (unweighted and A-weighted).

The mathematical tools are used to investigate the sound pressure characteristics of fans constructed with nonuniform blade spacing configurations. The theoretical analysis, which was verified experimentally, shows that the distribution of sound pressure in the frequency spectrum can be accurately predicted as a function of fan rotational frequency and blade spacing configuration. Fans with blade spacing configurations possessing a high degree of nonuniformity are shown to produce sound frequency spectrums which contain many discrete frequency components with similar magnitudes but with no outstanding discrete frequency components.

A method is proposed for selecting a fan with an optimum blade spacing configuration such that the discrete frequency sound pressure components generated by the fan do not strongly reinforce discrete frequency sound pressure components inherent in the immediate environment external to the fan.

Air delivery characteristics of axial flow fans are not analyzed in this study.

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750776. Acoustic Performance of a Large Semi-Anechoic

Test Chamber. Walker H. Flint, Caterpillar Tractor Co.

This paper describes a large indoor semi-anechoic facility for testing construction machines and discusses the procedures used to determine its acoustic performance characteristics. Data were obtained and analyzed employing controlled pure tone and broad band noise sources with varied microphone distances and elevations. The ground-plane microphone proved to be the most practical way to obtain representative data. Comparisons to an outdoor test site are included.

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750777. The Noise Box Test: A Novel Method for Evaluating Sound Absorbers. W. R. Powers and C. D. Rudinoff, Specialty Composites Corp.

A novel test method for evaluating sound absorbing materials has been developed. The Noise Box Test makes it possible to study many of the characteristics of an absorber (permeability, thickness, membrane weight, etc.) which affect its performance and, consequently, the manner in which an absorber can best be utilized. This type of test offers certain advantages over existing test methods. The Noise Box is much less expensive than a reverberation room. In comparison to the standing wave tube, the Noise Box Test utilizes a more reasonable sample size and measures performance under conditions of random incidence. The test is believed to be particularly useful for evaluating absorbers for industrial noise control.

750779. Design Concepts of the 400 Series Scrapers. R. A. Wade, Pay Line Div., International Harvester Co.

A family of four scrapers has been developed to provide operational versatility while emphasizing physical commonality. The wide variety of operational requirements encountered by scrapers were considered and related to the basic type of scraper best suited for the particular conditions.

Many vehicle systems were designed to provide maximum commonality between the single and dual engine, open bowl and elevating machines. Various new features were developed to improve vehicle performance and ease of operation.

750781. Laboratory Engine Performance Testing and Development of Two-Cycle Oils. A. F. Gerber, W. J. Lendener and T. R. Mullen, Product and Process Research Div., Cities Service Oil Co.

An engine test has been developed which differentiates the cleanliness characteristics of two-cycle lubricants. This test procedure utilizes an air-cooled Yamaha motorcycle engine and is run using a cyclic operating procedure for 20 hours. Test severity in the ring belt area is controlled by combustion chamber temperatures and fuel consumption rates.

Utilizing these techniques, programs were conducted which were directed to the development of improved two-cycle lubricants using the present BIA TC-W(1,2) reference oil as a baseline. The effects of various parameters of lubricant formulation were determined including concentration effects of the additive presently used in the TC-W reference, bright stock content, and the use of supplementary additives.

750782. Pesticide Application Equipment—How Federal Regulations on Pest Control Affect It. E. H. Fisher, University of Wisconsin—Madison.

Engineers have an opportunity to develop pesticide application equipment that will help prevent unreasonable adverse effects of pesticides on the environment, including humans. Recent and continuing federal regulations on uses of pesticides emphasize legal requirements for specific methods of pesticide application. Also the regulations incite development of pesticide application techniques that would allow restricted use pesticide product labels to be changed to the general use classification. The product could then be used by the general public, as opposed to only those certified as competent to use the otherwise restricted product.

Among present needs are improvements in, or development of: positive shut-off nozzles, calibration-sensitive granule applicators, soil incorporation of pesticide granules, planting time placement of soil-incorporated insecticide that is mixed with either dry or liquid fertilizer, post crop emergence soil pesticide incorporation, dry bait placement at plant base, dry bait broadcasting, and metering controls.

750783. Pesticide Safety Laws Challenge the Engineer. Robert W. Brazelton, University of California at Davis; and Keith L. Maddy, California Department of Food and Agriculture.

Incidents involving poison exposure of workers who have come in contact with toxic agricultural chemicals have prompted detailed analysis of pesticide related illnesses in California. Workers compensation insurance claim records and statewide surveys have clearly indicated the extent of such illnesses in the state. These same statistics provide no evidence of the massive numbers of occupational illnesses or fatalities following pesticide exposure as alluded to in some newspaper accounts but do indeed document the need for prevention pesticide-related illnesses. California's pesticide worker safety regulations developed to fill this need are discussed in some detail to inform prospective farm machinery manufacturers of the particular areas of machine design where the engineer can make a major contribution toward the elimination of such illnesses by incorporating certain design features in pesticide spray equipment and tractor design. The idea of a pesticide-free worker's environment is discussed, and the demanding need for engineering compromise in attaining it is defined. Prototype systems and major design needs are reviewed, but the ultimate machine design solutions

not yet developed remain to challenge the engineer.

750785. Training Materials for Agricultural Safety and Health. J. B. Liljedahl and F. R. Willsey, Purdue University; and David Martin, OSHA, Dept. of Labor.

An interdisciplinary team from Purdue University is developing a comprehensive set of educational materials for agricultural safety and health for OSHA, of the U.S. Department of Labor. The team from the Purdue School of Agriculture, school of Veterinary Medicine, and the school of Humanities, Social Science and Education are working for a year and a half to gather and catalog all existing safety materials, and to produce new ones to meet nationwide needs. The project was begun on July 1, 1974 and is scheduled to be completed by December 31, 1975.

The project team includes John B. Liljedahl, professor of agricultural engineering, project leader; Avery H. Gray, assistant department head, 4-H and Youth; William H. Hamilton, agricultural education; David H. Loewer, Extension agricultural engineer; David L. Matthew, Extension Entomologist; Vernon B. Mayrose, Extension animal scientist; Ken Weinland, Extension veterinarian; Bruce A. McKenzie, Extension agricultural engineer; James L. Williams, professor of Weed Science; and F. Richard Willsey, Extension safety specialist, co-leaders and Gay L. White, Extension information specialist, project writer-editor.

750786. Prediction of Radiative Heat Flux in a Diesel Engine. Takeshi Kunitomo and Kazuo Matsuoka, Dept. of Mechanical Engineering, Kyoto University (Japan); and Tatsu Oguri, Dept. of Mechanical Engineering, Yokohama National University (Japan).

The prediction procedure for the instantaneous radiative heat flux from the flame to the wall in a diesel engine combustion chamber is presented. By regarding the unsteady flame in a diesel engine as quasi-steady, the results obtained in experiments on radiative heat transfer in steady confined flames are applied. The concept of effective excess air ratio which controls the luminous flame radiation and which is strongly related to the fuel properties is introduced. The calculation is easily carried out by using pressure, heat release rate, effective excess air ratio, overall excess air ratio, and a simple model for temperature. A very good agreement is obtained between calculation and the experiment.

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750787. Efficient and Clean Diesel Combustion. S. J. Pachernegg, AVL (Austria).

Since the available combination of equations describing the kinetic reactions during diesel combustion a) is complicated, b) falls short in predicting actual NO-emissions, an attempt is made with a simplified model to correlate the squared temperature profile of the cycle over time, integrated above the level of a significant threshold temperature, with NO_x formation. This rating permits the evaluation of cycle parameters, like compression ratio, ignition timing, heat release and others, regarding their effect on the compromise between acceptable emission and cycle efficiency.

The underlying working theories compare and complement existing analytical models of diesel ignition, combustion and soot emission.

750788. Exhaust Emissions from Farm, Construction, and Industrial Engines and Their Impact. Charles T. Hare and Karl J. Springer, Southwest Research Institute; and Thomas A. Huls, U.S. Environmental Protection Agency.

The research program on which this paper is based included both laboratory emission measurements and extrapolation of results to the national population of heavy-duty farm, construction, and industrial engines. Emission tests were made on four gasoline engines and eight diesel engines typical of those used in F, C, and I equipment. Gaseous and particulate emissions were measured during engine operation on well-accepted steady-state procedures, and diesel smoke was measured during both steady-state conditions and the Federal smoke test cycle.

Emissions measured were hydrocarbons, CO, CO_2, NO, NO_x, O_2, aliphatic aldehydes, light hydrocarbons, particulate, and smoke. Emission of sulfur oxides (SO_x) was estimated on the basis of fuel consumed, and both evaporative and blowby hydrocarbons were also estimated where applicable (gasoline engines only).

Data on emissions obtained from this study were compared with those available in the literature, where possible. Other data on equipment size, usage, and population were used with the emissions data to estimate national emissions impact. Emission factors and impact estimates were made separately for each application category (farm, construction, industrial), resulting in the conclusion that these application categories contribute a small, but significant, portion of national pollutant totals.

Discussion: T. C. Young, EMA.

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750789. Four Stroke Motorcycle Engines, A Study of Their Lubricating Oil Requirements. M. J. DeJev and B. Brandone, Compagnie Francaise de Raffinage (France).

This paper shows how new formulations of oils, resistant to the particularly severe conditions in four stroke motorcycle engines, have been evolved. New bench test procedures, developed from the field, racing surveys and road tests, were used for the study of the following variables: oil film and oil consumption (viscosity), piston failure (scuffing and preignition) oil oxidation (thickening), piston cleanliness (dispersancy, detergency) and low temperature starting properties.

Introduction: Severity of motorcycle engines
Lubrication of motorcycle engines

Road tests
Bench test facilities
Test procedure study
Oil study—Part I: Viscosity
Part II: Choice of additive treatment
Part III: Significance of the test results
Part IV: Synthetic oils
Low temperature starting properties
Conclusion

750790. Multi-Purpose Engine Lubricant for Mixed Fleet Operation. G. C. Fleischhack, Deutsche BP Aktiengesellschaft (Germany).

An engine lubricant was developed for diesel and gasoline engines covering all service and climatic conditions in Central Europe.

The performance spectrum and reasons for formulating a SAE 20W-40 multigrade with a viscosity of 4800 cP at 0°F are explained.

A review of the development and test work conducted includes studies indicating the lubricants behaviour in gear boxes, hydraulic systems and other off-highway and construction equipment.

Typical examples of European mixed fleet together with service results obtained from the field are demonstrated.

Data compiled show stay-in-grade characteristics, excellent wear protection and engine cleanliness.

In comparison with SAE 20W-20 and SAE 30 monogrades oil consumption is reduced.

750791. Experiences with Multigrade Heavy Duty Engine Oils in Military Gasoline and Diesel Engines. P. R. Morris, Ministry of Defence (United Kingdom).

In 1973 a modified SAE 10W-30 multigrade heavy duty engine oil designated OMD-75 was introduced into a wide variety of British Army equipment in place of the single SAE 10 and SAE 30 grades previously used. Generally the introduction of the multigrade engine oil into a wide variety of different equipments has been successful. However, some problems with the use of a multigrade engine oil in certain diesel air-cooled engines has been encountered probably associated with high base stock volatility. A number of other problems are also described and examples given where multigrade engine oils have caused difficulties. OMD-75 has been successfully used in Allison transmission systems.

The use of the "FZG" gear machine as a method of test for the shear stability of viscosity index improvers is described and results presented for a number of different types of polymers. The FZG machine was found to be more severe than a diesel-injector rig and no correlation seems to exist between the two different methods of test.

750792. Development of the Caterpillar 245 Excavator with Shovel Attachment. E. J. Hnilicka, Caterpillar Tractor Co.

The recently announced 245 Shovel Arrangement expands the versatility of Caterpillar Tractor Co.'s basic 245 Excavator. The development of the 245 Shovel as a prime mover for large excavations is discussed with cable shovels and wheel loaders as a frame of reference for comparison. Also discussed is the development of some of its unique features.

750794. Load Indicating Systems in Lifting Crane Service—J376a—A Case Study in the Revision of a Recommended Practice. G. A. Parker, Controls Div., Eaton Corp., J. J. Elengo, Revere Corp. of America; R. F. Griffin, R & D, Warner & Swasey Co., D. S. Schaner, Martin Decker Corp.; and J. W. Six, Lorain Div., Koehring Co.

The need for clear definition of accuracy performance and operating criteria for Load Indicating Systems has been voiced by crane operators, crane manufacturers, and legislative agencies. A thorough study of the existing Recommended Practice was undertaken with the specific goal to upgrade J376 to permit greater understanding of the minimum performance requirements of Load Indicating Systems.

750795. (SP-397) **The Problems of Noise of Engines in Different Vehicle Groups.** T. Priede, Automotive Engineering Group, University of Southampton (United Kingdom).

The paper classifies all current automotive engines into four distinct groups relative to engine usage and vehicle noise legislation.

The noise characteristics of the engines in each group are widely different except that at their maximum rated speeds the overall noise levels approach the same value.

The sources of noise rank in different importance according to the size and type of engine. Therefore quiet engine design must also vary.

The importance of mechanical noise is emphasised and it is considered that this source could be a limiting factor to future low noise engines.

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750796. (SP-397) **Noise, Emissions, and Performance of the Diesel Engine—A Comparison Between DI and IDI Combustion Systems.** Frank W. Leipold and Horst O. Hardenberg, Daimler-Benz AG (Germany).

A direct as well as an indirect injection system have been studied in regard to noise, exhaust emissions and fuel consumption on a V-10 diesel engine. The dependency of the sound pressure levels on engine speed, engine load and injection timing is described for both combustion systems. The noise reduction achieved by optimisation of injection timing is shown in relation to the respective changes in exhaust and smoke emission output and fuel consumption.

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750797. (SP-397) **Effect of Turbocharging on Diesel Engine Noise, Emissions and Performance.** D. Anderton and V. K. Duggal, Automotive Engineering Group, University of Southampton (United Kingdom).

The overall effect of two methods of turbo-charging a direct injection four stroke diesel engine in terms of performance, smoke, noise and gaseous emissions is described. It is shown that the effect of turbocharging is to produce a more socially acceptable engine. Matched turbocharging involving reduced compression ratios produces substantial emissions and combustion noise reductions (up to 16dB) at full load but can increase combustion noise levels considerably (8dB) at light load. Before full advantage can be taken, methods of controlling the characteristics of turbochargers to maintain short ignition delays at all conditions are required, together with reductions in engine mechanical noise levels.

750798. (SP-397) **The Effect of Combustion System on Engine Noise.** Bernard J. Challen, Ricardo & Co. Engineers (1927) Ltd. (United Kingdom).

The effects of using different combustion systems on engine noise are reviewed including an examination of noise reduction methods such as shielding, enclosure and structural modifications. Comparisons are made of direct injection and indirect injection systems and a new noise prediction formula for IDI engines is proposed.

The use of turbocharging is examined and the limiting effects of mechanical noise noted. The variation of exhaust emission levels with reduction of combustion noise is included.

750799. (SP-397) **Affecting Diesel Engine Noise by the Piston.** Manfred D. Rohrle, Mahle GmbH (Germany).

The ever increasing motorization is entailing, apart from all its positive effects on our way of life, also some aftermaths detrimental to mankind. Air pollution and noises have become serious problems. More and more people are getting environment-minded and strongly expect that this annoyance be checked, at least kept in tolerable limits. Experts in all industrialized countries are engaged in controlling disturbing noises and there can be no doubt that internal combustion engines, automotive Diesel engines in particular, are producing no small share of this kind of nuisance. Intensive attention is therefore being paid to the silencing of noises lately.

As far as mechanical engine noise is concerned the piston is a contributing element due to its side motion in the cylinder. The impulses caused by the slapping piston lead to cylinder wall acceleration and produce bone-conducted noise which travels axially and radially through the cylinder wall until it reaches the surface of the engine, from where it is radiated as airborne noise.

Since it is not possible to measure piston noises at their origin this paper deals with the methods of affecting the piston movements and the impact of the piston, as it hits the cylinder wall, by means of measurements with pistons whose pins are not offset, that is, on which the axis of piston and pin coincide. Moreover measurements are described with positively and negatively offset pins, whereby the pin axis is slightly displaced with respect to the piston axis.

After describing various designs of pistons with controlled thermal expansion and of the articulated piston, which allows to reduce the fitting clearance as compared with one-piece full-skirt pistons, this paper reports on noise measurements with such pistons and on the influence of skirt coatings on piston noise.

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750800. (SP-397) **Transverse Movement Analysis and Its Influence on Diesel Piston Design.** R. Munro, Wellworthy, Ltd. (United Kingdom); and A. Parker, A. E. Developments Ltd. (United Kingdom).

The latest advances made in the development in a theoretical analysis of piston movement are described, covering the introduction of such new features as non-parallel bores, ring/groove friction, conservation of angular momentum at impact, and kinetic energy loss at impact. A single value of friction co-efficient of 0.2″ is derived from experimental data and the new program is shown to give good agreement with measured piston movement traces.

The movement program is used to examine several piston design features in respect of their influence on impact severity and indicates the importance of gudgeon pin offset, piston/liner clearance and gudgeon pin height when considering piston noise.

Further study on the features of friction and impact conditions are suggested, and the work is seen to have wider implications in the development of a complete set of piston assembly predictive design techniques.

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750801. (SP-397) **Piston Slap Noise of Indirect Combustion Diesel Engine.** Takashi Usami, Shinji Wada and Shigeru Sonoda, Mitsubishi Motors Corp. (Japan).

Diesel trucks have four major noise sources: engine, cooling fan, exhaust systems and tyres.

It is generally found that on current trucks engine radiated noise is the most important source, the latter being mainly produced by piston slap. Particularly for reducing the noise of IDI engines, where combustion noise is comparatively low, control of piston slap is most important.

This paper gives some calculated results to predict piston behavior and compares them with measured information on engine noise and cylinder liner vibration where piston slap control measures have been taken.

From the experiments carried out at Mitsubishi Motors Corporation it is concluded that offsetting the piston pin is both the easiest and cheapest method of controlling piston slap on current production engines.

750802. (SP-397) **Injection Noise and Its Relation to Fuel Pump and Engine Noise.** Klaus D. Zimmermann, Robert Bosch GmbH (Germany).

It is often pretended that the injection nozzles of diesel engines are substantial noise generators. This statement was investigated on a truck diesel engine with the result that the nozzles are not a substantial source of noise on the engine. The task was to find out the principles as well as the composition of the noise components radiated from the nozzles.

Further investigations in an anechoic chamber revealed the cause of the nozzle noise and showed also several possibilities for its reduction.

750803. (SP-397) **Identification and Modeling of Rotary Fuel Injection Pump Noise Processes.** A. J. Herbert and M. F. Russell, Cay Ltd. (United Kingdom).

The contribution to the noise of automotive diesel engines from the DPA rotary fuel injection pump has been assessed by comparing its overall noise with that of a number of engines, to which the pump is, or may be fitted. From this data, a 'worst case' has been selected for a more detailed assessment. The noise generating mechanisms of the pump are examined. Two improvements are described which are suitable for mass production with existing facilities, and which reduce the overall noise by 3 to 5 db(A). An outline of a modular mathematical model is presented which will guide future efforts towards further practical cost-effective noise control.

750804. Energy Conservation—Electric Forklift Hydraulic Systems. Harley A. Harrom, White Materials Handling Co.

In order to obtain maximum work from an electric forklift truck, it is necessary from the designer's point of view to maximize systems efficiency. This paper discusses vehicle hydraulic systems and parameters affecting design, realizing that the truck is powered by a battery with finite energy storage capacity. Efficiency of hardware that hydraulics control is shown to be as important as hydraulic hardware selection and design per se, and duty cycle must also share equal consideration.

750805. Exploiting the Versatility of a Radial Piston Pump. James M. Bahl, Deere & Co.; and Arvid Waschek, John Deere Waterloo Tractor Works.

The mushrooming use of hydraulic power is resulting in demands for more flexibility and versatility in the power source. The radial piston pump is particularly well suited to meet present day demands as well as the needs of the future. It permits an unusual degree of flexibility in systems design.

This paper will show how this pump is being used as a source of power to operate either open or closed center systems using either open or closed loops.

It can be operated with controls which modulate pressure or flow or both, automatically, in response to load magnitude, speed, position, or temperature or in response to operator input and using a mechanical, electrical, hydraulic, sound, or light signal.

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750806. Load-Sensitive Hydrostatic Steering—A New Approach. J. L. Rau, Ross Gear Div., TRW, Inc.

Load-sensitive hydraulic control systems have demonstrated new potential high efficiency levels. Mobile equipment designs which widely utilize open and closed center circuits are being adapted to total centralized load-responsive stand-by systems to curtail fuel consumption and operating costs.

This paper outlines previous art in steering systems and highlights the design concepts required to adapt the steering function to load sensitive variable flow-pressure circuitry. Since the steering function power demands are normally low for corrective maneuvers, it is ideally suited to the environment of a central load-sensitive system. The general concept of a load-sensing steering valve and its relative design role to the other system components will be developed, emphasizing standard meter-in load-sensing technology. The possible new "feathered" and "absolute" type systems are introduced.

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750807. Controlling Variable Displacement Hydraulic Pumps for Energy Conservation. Allen Myers, Sundstrand Hydro-Transmission Div., Sundstrand Corp.

The possible causes of hydraulic power losses in both closed and open loop hydraulic systems are discussed. The means of minimizing these losses with the proper choice of closed versus open loop systems and with maximum utilization of variable displacement pump controllability are discussed. Also discussed are means of reducing prime mover size with pump power limiting controls to increase power generation efficiency. Examples are analyzed to illustrate the energy saving potential of closed loop pressure control, open loop pressure and flow compensation, and closed or open loop pump power limiters.

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750809. Effect of Fluid Temperature on the Performance of Friction Material. Robert L. Fish and Frederick A. Lloyd, Stratford Div., Raybestos-Manhattan, Inc.

The fact that temperature can affect the performance of friction material has long been recognized, and many studies of the phenomena have been made. For the most part, results have been contradictory and indicate a complex relationship between temperature and other variables that constitute the conditions of use. This paper offers a report on the continuing effort to establish the extent of change produced and the mechanism by which such change is effected. Data are presented on SAE #2 machine test of three friction materials in three oils controlled at varying temperature level.

How the temperature effects can be further modified by pressure or power loadings are also demonstrated. In addition, study of friction hysteresis with temperature —performance at temperature as affected by previous history—is included. Theories are proposed to explain trends noted in the data. While these are intended to aid in optimizing design for specific units, the need for further study to improve understanding in this area is implied.

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750810. The Operation of Elastomeric Radial Lip Seals at High Temperatures. L. A. Horve, Chicago Rawhide Manufacturing Co.

The evolution of the modern elastomeric radial lip seal parallels the evolution of the automobile. Higher operating temperatures in modern automotive applications are approaching the limits of present seal designs and materials.

Seal ultimate life depends upon the ability of the seal design and material to resist heat. At elevated temperatures, seals may become hard and brittle, blister, crack, and degrade. High wear may also result.

Improvement of seal performance at elevated sump temperatures can be obtained with modern seal design and materials.

750811. Allis-Chalmers 7000 Agricultural Tractor. Ernest A. Kreitzberg, Allis-Chalmers Corp.

The Allis-Chalmers Model 7000 tractor, rated at 105 PTO hp, is an extension of the Allis-Chalmers new family concept (originally introduced in 1973) into the intermediate tractor class.

This paper presents an overall description of the tractor and the engineering program required for development.

750812. What Are The Benefits of Monitoring? Ronald W. Steffen and James H. Anson, DICKEY-john Corporation.

Agricultural electronics (Agrionics) provide vital information and control for the modern farmer to improve his decision-making capabilities. The large and complex equipment utilized in modern day agriculture demands monitoring equipment. Guesswork adjustments on machinery are no longer acceptable with the competitive markets and environmental concerns in agriculture today.

With increased interest in fuel conservation, ecology, operator environment, and efficiency of machine operation, monitoring is rapidly growing from a luxury to a necessity. The result is that all of us who must eventually consume the end result of agriculture—food—will benefit.

750813. Automatic Vehicle to Form Free Standing Stacks of Baled Hay. Edward Wynn and Lee Dennis Butler, Sperry New Holland.

A self propelled vehicle has been developed which automatically forms a stack of hay bales with interlocking tiers. The stacks made with this vehicle show significant improvements in stability and appearance as well as providing a hay stack which can be mechanically loaded on transport trucks. Introduction of this vehicle will greatly influence the future trends in baled hay handling in the far western part of the United States.

750814. Time and Motion Study Used to Determine Tractor Design Parameters. Gary Krutz, Agricultural Engineering Dept., Michigan State University.

Many different methods are now being utilized in aiding engineers to determine significant parameters for designing tractor components. The technique discussed in this paper utilizes time-lapse photography in a time-and-motion study of industrial tractors. This time-lapse method makes the determination of vehicle parameters easier and more reliable. Vehicle parameters determined by this method are productivity, cycle times, operating procedures, operator movements and machine lost time.

Every engineer would like more information in designing a final product. At present, this information is acquired by marketing feedback, service reports or testing the product. In most cases the engineer is still left grasping for more information regarding how this machine is used and what types of operations does it really go through. Such information would be very useful in product life determinations now that increased emphasis is being placed on product reliability in the courts.

Instrumenting a tractor and testing it to gather the data can be an expensive operation while market feedback is by word of mouth and too many biases are created.

A new approach in time and motion study was applied to gathering engineering data. The type of data that was acquired by this method included usage time per week, average engine RPM, percent time on various jobs, average and peak cycle times for loaders and backhoe work, backhoe swing cycle times and angle of swing, operator corrections needed for backhoe work, average trench depth, operator movements, operator comments and general system procedures for dumping, peeling or scraping with a loader.

750815. Today's Mineral Problems and a Look at the Coming Decade. John D. Morgan, Jr., Bureau of Mines, Dept. of the Interior.

Materials and energy are the lifeblood of our industrialized economy. Annually the United States uses over 4 billion tons of mineral materials and fuels. Domestic processed materials of mineral origin and energy are valued at more than $210 billion annually, derived largely from domestic sources, supplemented by imports. We now find increasing competition in world markets when it comes to acquiring needed raw materials, while at the same time we also find strenuous competition in selling many manufactured articles. Increased efficiency in our mining, minerals, metal, mineral reclamation, energy, and transportation industries requires accelerated development of new and improved technology.

750816. Selection for Technical Leadership. T. J. A. Hughes, United Kingdom Land Forces.

The purpose of this paper is to describe a system of selection for technical leadership which has been developed in the UK's Royal Electrical and Mechanical Engineer Corps. It has been refined over the years into an effective method of selecting young men with qualities which have taken them to responsible positions in technical management.

750817. 21 Cubic Yard 580 PAY® Loader. Prem L. Ajwani, Pay Line Div., International Harvester, Co.

To effectively utilize larger trucks (85 ton and up), open-pit mines and quarries need a larger front-end loader with high reliability and performance. This paper describes the design approach and tests carried out to design 21 cubic yard 580 PAY® loader to meet these requirements.

Long fatigue life of structures was obtained by use of full penetration welds. New concept for power control was designed to effectively distribute power between hydraulics and drive train. Spring applied - pressure released brakes were designed into the axle. Tests were carried out in our laboratory and proving grounds to determine performance and reliability.

750818. The TDMC-33-7002: A 1500 HP Transmission for Shuttle Type Vehicles. Joseph B. Snoy, Marvin W. Dundore and Paul A. Pelligrino, Twin Disc, Inc.

The growth in actual size and capability of construction equipment has created a need for new power train designs to handle the tremendous energies which must be absorbed during shift reversals. This paper discusses the TDMC-33-7002, a three-speed, full-reversing shuttle type transmission developed by Twin Disc, Inc., at the request of International Harvester for a transmission system for their 580 Pay Loader. Problems, both expected and unexpected, that arose during the design and development of the transmission-converter system are explored, and new criteria for larger end loaders has been determined.

750819. A Nonlinear Automatic Feedback Blade Controller for Improved Bulldozer Performance. Kazuhiko Ohtsubo, Komatsu, Ltd. (Japan); and E. Dawson Ward, School of Mechanical Engineering, Purdue University.

Underwater bulldozers have been built for development of the ocean floor. Yet it is impractical for a diver to operate an underwater bulldozer from within the vehicle. Remote control of a bulldozer is extremely difficult due to complicated relationships between vehicle inclination, blade cylinder deflection, and the terrain profile in front of the bulldozer. In this paper a nonlinear automatic feedback blade control system is designed to replace direct operator control of the blade.

To accomplish this design, mathematical models were developed for the vehicle dynamics and the hydraulic system dynamics of a typical bulldozer. Since both subsystem models are complicated nonlinear ones, the blade control system was designed using only a simplified hydraulic system model. The performance of the complete nonlinear system with the blade feedback control system added was then investigated using a hybrid computer simulation compared to available experimental data using a skilled operator.

Based on cutting accuracy for a simple cutting task, the simulated bulldozer system with the new proposed feedback blade controller performed at least as well as a skilled operator on dry land. This success appears to warrant further research and the development of an actual hardware prototype.

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750821. A Prognostic Simulation Technique for Fluid Power Systems. S. K. R. Iyengar, Fluid Power Research Center, Oklahoma State University.

The development of the Statistical Analog Monitor (STAM) has resulted in the availability of data which could be invaluable in setting up maintenance schedules and procedures. This paper presents one method of using STAM data along with other information about the machine and its task to appraise the state of its components. The machine duty cycle is simulated using a set of characteristic parameters which depict the state of critical components. These data are then used to develop a library of STAM profiles against which actually collected profiles may be compared. An example system is analyzed to indicate the changes in STAM profiles due to degradation of selected components.

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750822. The Nature of Abrasive Wear. Howard S. Avery, Abex Corp.

The terms abrasion and erosion mean different things to various people. Moreover, there are many devices for measuring the response of materials to abrasive wear. The results from such machines do not consistently agree with those of the others because variables that differ in kind and amount are involved.

Classification areas that help define the variables are an aid to the selection and application of laboratory and service tests. To three categories previously proposed by the author, and widely adopted, four others are now added for completeness and in hopes that misapplication of the terminology will be minimized. These are described and in several cases linked to better known laboratory tests.

Of the categories: clean fluid erosion, impingement-erosion, erosion (as a simplified term) meaning parallel-flow low-stress abrasion, gouging-abrasion and erosion-corrosion; most attention is given to parallel-flow erosion because it seems most pertinent to the abrasion problems of automotive engineers and it is at present the focus of the SAE committee work with rubber-wheel erosion tests.

A suggestive check-list of variables to be identified and described when reporting abrasion tests is provided.

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750827. Vehicle Evaluation of Synthetic and Conventional Engine Oils. John J. Rodgers and Richard H. Kabel, Research Laboratories, General Motors Corp.

A five-vehicle, 64 000-km test with 7.45 litre V-8 engines was conducted to determine if synthetic engine oils provided performance sufficiently superior to that of conventional engine oils to permit longer oil change intervals. The results show better performance in two areas of deposit control; inferior performance with respect to wear protection; and essentially equivalent performance in the areas of fuel and oil economies. Based on these data, it was concluded that synthetic engine oils do not provide the necessary performance required to safely recommend their use for extended oil change intervals. In addition, a cost analysis shows that the use of synthetic engine oils, even at a change interval of 32 000 km, will essentially double the customers' cost compared with conventional engine oils at GM's current 12 000-km change interval.

750828. Application of Synthetic Engine Oils in Army Hydraulic and Power Transmission Fluid Systems. P. D. Hopler, U.S. Army Mobility Equipment Research & Development Center; and S. J. Lestz, U.S. Army Fuels and Lubricants Research Laboratory.

Development of the Army's new Arctic Engine Oil (OEA) Specification MIL-L-46167 required numerous laboratory and field engine evaluations as well as large scale laboratory and field testing of these new lubricants in military hydraulic and power transmission fluid systems (HPTF). An earlier SAE paper emphasized the engine performance aspects of these synthetic oils, and now the current paper points up and emphasizes the significant performance areas in military HPTF systems. The new oils function well as year-round lubricants in Army HPTF systems including: automatic and power-shift transmissions, power steering units, hydraulic winches, pumps, and mechanical and construction equipment hydraulic systems. It appears that the new synthetic arctic engine oils have significant potential military applications in HPTF systems *outside* arctic regions as well as *inside* the arctic. Problem areas are discussed and a recommendation is advanced for the development of a truly "universal" HPTF.

750829. Effect of a Pulse Damper on a Hydraulic System on Operator Ear Noise. R. L. Rainwater, Industrial Equipment, Ford Tractor Operations.

The basic theory of an expansion chamber assumes an infinite straight outlet tube and no reflected waves; neither of these conditions exist in practice since a vehicle's hydraulic system contains a finite length of tubing with bends, constrictions, and valves. These complicating factors make the reduction of fluidborne noise a system design problem rather than only a component design problem. Despite these problems and packaging problems which prevented the optimization of the filter design, very significant operator ear noise reduction was achieved by addition of the expansion chamber in the hydraulic system of a certain prototype tractor with cab.

750830. Rating Pump Fluidborne Noise. S. F. Szerlag, Sperry-Vickers.

Measurements of pump fluidborne noise can be influenced to a considerable degree by the effects of standing waves and volume compressibility within the discharge line. In the absence of a standard procedure for handling these effects, it is difficult to make comparisons of pump fluidborne noise data and to use such data in low noise system design. This paper discusses the influence of discharge line parameters on fluidborne noise measurements and proposes a simplified test procedure for determining the inherent fluidborne noise level of a pump. Results from experimental and analytical investigations are described.

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750831. Fluidborne Noise Attenuator Performance Evaluation. G. E. Maroney, Fluid Power Research Center, Oklahoma State University; and S. E. Wehr, U.S. Army Mobility Equipment Research and Development Center.

This paper discusses an engineering technique for evaluating the performance of fluidborne noise attenuators based on parameters of pressure drop as a function of flow rate and pressure ripple attenuation as a function of frequency. The selection of pressure ripple measurement points, the number of measurement points, and the interpretation of the test results are related to acoustical plane wave theory. Specific recommendations are made for a reference level and reference center frequencies for reporting transmission loss in dB.

Discussion: Dennis L. O'Neal, Not available.

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750832. (SP-397) Analysis and Prediction of Engine Structure Vibration. M. G. Hawkins and R. Southall, Perkins Engines Ltd. (United Kingdom).

The work described in this paper was undertaken as part of a program aimed at predicting engine noise and vibration characteristics at the design stage.

The initial work was carried out on simplified two dimensional plate structures and a simple three dimensional model. Surface vibration and noise levels were predicted and compared with measured vibration levels and mode shapes are given for an in-line six cylinder diesel engine.

The prediction of noise at the design stage relies upon the calculation of surface response levels. Supplementary tests on engine components to determine damping are reported. The approach to Force level simulation over a broad frequency band is also considered.

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750833. (SP-397) **Modes of Engine Structure Vibration as a Source of Noise.** N. Lalor and M. Petyt, Institute of Sound & Vibration Research, University of Southampton (United Kingdom).

This paper presents the results of recent investigations carried out at I.S.V.R. into the mechanism of structurally radiated noise.

The overall modal characteristics of a simplified engine structure have been analysed theoretically using finite element programs developed at I.S.V.R. and a comparison is made with experimental results obtained on an equivalent physical model cast in one piece to minimise damping. These results have given an important new insight into the vibration behaviour of a typical engine block casting.

The mechanism whereby the modes of vibration of a typical engine structure are excited by the forces in each cylinder is analysed in conjunction with experimental results obtained by a novel static deflection technique. Also presented are the results of a study into the optimum way of isolating a light panel from block induced vibration.

The acoustic power radiated by representative modes of engine vibration through the acoustically important frequency range is discussed and some results of directivity tests are also given.

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750834. (SP-397) **Simple Model Technique for Better Understanding of Diesel Engine Vibration and Noise.** Kazuomi Ochiai, Masaharu Aisaka and Seiji Sakata, Isuzu Motors, Ltd. (Japan).

This paper describes an approach to predict the dynamic behaviour and the radiating noise of the diesel engine structure.

Nowadays, all diesel engine designers have to pay their prime attentions to engine specifications so as to meet more stringent future governmental control standards both in exhaust emissions and noise.

For this purpose, it is absolutely necessary to establish criteria that can predict in the early stage of design the vibration modes and their noise levels inherent in individual engine structures so that the most cost-effective engine designs from the noise point of view can be screened out.

Some basic experimental results obtained by using a simple structure model to develop such design criteria are described in this paper.

Natural frequencies and the vibration modes of the structure are calculated by finite element method and the results are ascertained both by accelerometers and holography. It was found that the latter was more effective for accurate measurements of vibration modes and phase than the former. A very good agreement was observed between the calculated results and the actual measurements.

Some results obtained by the application of holography to a real engine structure as a means to make its vibration characteristics clear are also mentioned.

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750835. (SP-397) **Techniques of Structural Vibration Analysis Applied to Diesel Engine Noise Reduction.** R. S. Lane and S. E. Timour, Cummins Engine Co., Inc.; and G. W. Hawkins, Massachusetts Institute of Technology.

This paper presents several techniques used to define quantitatively the problem of excessive noise through engine structural vibration. These techniques include both operating engine tests and bench tests. In addition, analytical techniques are shown which give a better understanding of how the critical components within the engine cause this vibration.

Through the use of analytical and experimental techniques, examples illustrate practical solutions for diesel engine noise reduction.

750836. (SP-397) **The Application of Idealization and Response Analysis to Diesel Engine Noise Assessment.** P. J. Yorke, Perkins Engines Co. (United Kingdom).

A method of determining the contributions to noise radiated by a diesel engine using idealization and response analysis is described. An idealization of the engine surface as a set of flat plates is used to calculate radiation efficiency from physical properties and edge constraints of each plate, and the velocity response of the engine surface is measured using accelerometers. This data is used in a simple acoustical power relationship to determine 1/3 octave sound pressure levels under free field conditions for the engine and individual noise sources on the engine. The theory is discussed and an example of the application of the method is given, and compared briefly with the more traditional noise source identification technique of lead cladding.

750837. (SP-397) **Practical Means for Reducing the Noise of Fast Diesel Engines.** M. Le Creurer and M. Marty, Automobiles Peugeot (France).

Substantial efforts have been made for the last ten years with a view to reducing the noise level of private cars equipped with high speed Diesel engines. Among others, such efforts resulted in a substantial reduction of the characteristic diesel engine noise at idling speed as well as in a substantial improvement of acoustical comfort within the vehicle passenger compartment.

More recently, systematic studies were conducted with a view to reducing the external noise level of such vehicles under urban traffic conditions. The main criterion

retained was the noise level as measured under conditions specified by ISO Standard R 362.

Significant progress has already been made to reduce noise connected with fuel injection and combustion. With current engines, engine high speed noise is primarily mechanical. It is not contemplated, at least in the short term, to put in production an engine designed on a fundamental new basis, on account of the large investments involved, and of the required time for resolving technical and industrial problems.

Under such conditions, possibilities for reducing noise directly at its source remain very limited, since they mainly concern modifications to housings, especially the timing cover and oil pan. Also studied was the possibility of reducing noise by means of insulating screens and absorbing materials in the engine compartment.

The impact of a reduction in the noise from the engine itself is substantial only provided that the noise from other sources is also limited, such as from the exhaust system, intake system, cooling fan and clutch-gearbox-transmission assembly.

As from now, the noise level of private cars equipped with high speed Diesel engines under legislated conditions currently in force in Europe, is no higher than for other vehicles of the same class.

In spite of difficulties inherent to the Diesel engine, the fact is stressed that most solutions retained or contemplated with a view to reducing outer noise levels are applicable to private cars equipped with spark ignition engines.

750838. (SP-397) **Design Concepts of Diesel Engines with Low Noise Emission.** Gerhard E. Thien and Heinz A. Fachbach, Anstalt fur Verbrennungsmotoren Prof. Dr. Dr. h. c. Hans List (AVL) (Austria).

The sources of diesel engine noise and methods for its abatement are analysed and described. Typically, the overall engine noise is determined by the engine surface noise which, however, can hardly be reduced by more than 5 dB(A) with conventional noise abatement techniques. For reductions of 10 dB(A) or more, it is necessary to attenuate the noise of all external engine parts by a complete encasing of the engine. Various concepts for light weight acoustic engine casings which are closely fitted to the engine without acoustical lining or even integrated into the engine structure and which provide a 15 to 20 dB(A) noise reduction are demonstrated, including one concept for future light weight engines featuring a sound attenuating housing.

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750839. (SP-397) **Techniques for Quieting the Diesel.** D. F. Kabele and G. A. Anderkay, John Deere Waterloo Tractor Works.

Reduction of diesel engine noise in a cost-effective manner requires quantitative identification of the noise levels radiated by the different engine surfaces. The source identification enclosure technique and test variation effects are discussed. In addition, the techniques of optimum mass and stiffness distribution, shielding, damping and isolation are discussed and results of typical treatments are shown.

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750840. (SP-397) **Low Noise Opposed Piston Two-Stroke Engine and Blower.** D. W. Tryhorn, Sir W. G. Armstrong Whitworth & Co., (Engineers) Ltd. (United Kingdom); H. L. Pullen and E. C. Grover, Institute of Sound & Vibration Research, University of Southampton (United Kingdom).

The paper divides into two parts. First the investigation of the noise of an unconventional design of two cycle diesel engine, including the results of applying known noise reducing features to it. Then taking one component of that engine, the scavenge blower, and re-designing it from first principles to produce a low noise machine suitable for the low noise engine. The final assembly of engine and blower demonstrated that the noise that has been regarded the characteristic of the two cycle engine is in fact that of the Roots type blower and when eliminated the noise level can be quite low. The present test bed noise level of 97/98 dBA at 1 metre shows promise of this type of engine meeting the legislative requirements of the 1980s.

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750841. (SP-397) **Noise—The Diesel Engine Designers' Dilemma.** A. M. Porkess and R. J. Rice, Truck and Bus Div., British Leyland, Ltd. (United Kingdom).

This paper attempts to put into perspective the noise position of the automotive diesel for the present and the future. It comments on some of the noise measuring techniques and in particular emphasises the importance of knowing the noise characteristics of each design of engine.

750843. **Failsafe Brake for Hydrostatic Drives.** John W. Euler, Auto Specialties Mfg. Co.

An automatic brake has been developed to provide emergency braking and positive position control in hydrostatic drive applications. The brake is automatically applied with the loss of hydraulic pressure to provide the emergency braking function. The brake may be applied at any time by manually dumping the fluid pressure to the brake, to provide the position control function of a parking brake. Because of the convenient mounting of the brake between the hydraulic motor and a gear reducer, the brake may be used in any hydrostatic drive application where position control and/or emergency braking is required.

750845. **Lube Oil Filter Evaluation.** L. E. Bensch, Fluid Power Research Center, Oklahoma State University.

A new and meaningful test method for evaluating the

performance of lubricating oil filters has been developed under the sponsorship of the U.S. Army MERDC. The test procedure is based upon the multi-pass method previously formulated for hydraulic fluid power filters, which has since been accepted on both national and international levels. The multi-pass procedure assesses only the particle separation characteristics of a filter and isolates all other factors which could influence the results. The development effort which resulted in this new lube oil filter test method required an international opinion survey, industrial advisory meetings, and an extensive testing program. Details of the method are given in this paper along with repeatability and discriminatory test results.

750846. The Effect of By-Pass Valve Leakage on Filter Performance. R. K. Tessman, Fluid Power Research Center, Oklahoma State University.

The separation performance of a filter element used in a hydraulic system to protect critical components can be seriously degraded by permitting fluid to by-pass the filter element. Such by-pass leakage paths stem from many different causes. For example, an element that is improperly sealed within the housing will permit a portion of the inlet flow to by-pass the filter. Damaged elements are another source of possible by-pass leakage. There is one leakage path, however, which is seldom considered in a contamination control analysis – *by-pass valve leakage.* Such a valve is placed in a filter housing to protect the element from excessive pressure differential and is sometimes referred to as a *filter relief valve.*

This paper develops an analytical expression which describes the influence of leakage flow on the separation performance of a filter. Actual data associated with the flow-pressure drop characteristics of both commercially available filter elements and by-pass valves are utilized to illustrate the leakage flow relative to such valves. Graphical illustrations are used to demonstrate the performance deterioration due to by-pass valve leakage.

750847. Filter Selection Based on Component Sensitivity Analysis. E. C. Fitch, Fluid Power Research Center, Oklahoma State University.

As a result of the advancement of two significant test procedures — the Multi-Pass Test for Filters and the Contaminant Sensitivity Test for Components— a totally new filter selection method has evolved. This method considers the severity of the application, the sensitivity of the components, and the particle capture capability of a filter. The paper introduces for the first time a filter selection chart concept which reveals the influence of operating pressure, contaminant ingression, and desired service life on the selection process. Emphasis is placed on user-oriented information, and the type of charts which component manufacturers could supply the user as well as the type of charts the filter manufacturer could supply are illustrated.

750848. A Fundamental Investigation into the Problem of NO Formation in Diesel Engines. David R. Nightingale, Ricardo & Co. Engineers (1927) Ltd. (United Kingdom).

In order to supplement the on-going development work aimed at reducing emissions levels, in particular NO, in the exhaust of diesel engines a research programme was initiated to investigate the fundamental nature of NO formation.

A rapid acting sampling valve to obtain gas samples directly from the combustion chamber of a running diesel engine was developed concurrently with a mathematical model for the formation of NO in diesel engines, based on the extended Zeldovich mechanism.

Gas samples were obtained from the following types of diesel engine:

i) A single spray sector of a large quiescent direct injection combustion chamber

ii) A deep bowl direct injection combustion chamber employing inlet induced swirl

iii) A Ricardo Comet V indirect injection combustion system.

The temporal and spacial distribution of NO and the local air fuel ratio were determined in each case.

The model depended heavily on the information provided by the gas samples which, in conjunction with high speed photography of the combustion process, indicated that NO was formed only in gases exposed to high temperature flame and that any NO found in cooler areas of fresh air or weaker mixture appeared there solely by mixing with the hot gases, despite the high oxygen concentration. In addition the delay between the combustion and the appearance of NO is clearly shown and this allowed considerable simplification of the model in that only the reactions involved in NO formation needed to be considered kinetically in order to give good correlation between experimental and theoretically predicted exhaust NO content over most of the engine operating range.

It is concluded that the gas sampling valve proved to be a valuable tool in understanding the fundamentals of NO formation in particular and combustion problems in general and greatly assisted in the formulation of a mathematical model for prediction of NO emissions from diesel engines.

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750849. Diesel Combustion Chamber Sampling — Hardware, Procedures, and Data Interpretation. James E. Bennethum, James N. Mattavi and Richard R. Toepel, Research Laboratories, General Motors Corp.

In-cylinder sampling appears to be the only available means for obtaining detailed information of the diesel combustion process. This information is necessary to understand pollutant formation because of the intimate relationship between formation rates and local cylinder conditions.

This paper discusses efforts to (1) examine and improve sampling valve design, (2) evaluate potential effects of the valve and the sampling system on sample composition, (3) find methods to extract useful information from sampling data.

Sampling hardware is currently being used to study combustion in engines, but further work is needed to quantify the influence of hardware and procedures on sample composition and to design experiments to provide data containing maximum information.

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750851. Non-Wearing Ferrofluidic Seals. Ronald Moskowitz and Frederick D. Ezekiel, Ferrofluidics Corp.

Ferrofluidic seals utilize a non-wearing "liquid O-ring" of magnetic fluid as a positive hermetic barrier. These seals have become established art and are now widely used in vacuum and nuclear systems for rotary shaft penetrations and in gas pressure systems. Leakage rate is immeasurably low (less than 10^{-11} std. cc/sec of helium) as measured on a mass spectrometer. The liquid seal is generally forgiving of surface finish, mechanical run-out and eccentricity. Fluids of many different physico-chemical families have been developed for operating under widely differing conditions — diesters for vacuum and wide temperature range; fluorocarbons for highly reactive environments such as chlorine, ozone, sulphur dioxide and acidic vapors; and polyphenylethers for ultra-hard vacuum and maximum radiation resistance.

They have also found wide application as exclusion seals preventing liquid, vapor, metallic and non-metallic contaminants from reaching machinery parts in applications such as digital disc drives, grinding spindles and textile wind-up heads.

New engineering developments now make these seals applicable on oil systems for gear boxes, transmissions, drives and other sealed lubrication systems where they totally contain the oil while excluding external contaminants.

This paper reviews the rapidly advancing state-of-the-art of ferrofluidic seals including sealing vacuum, gases, liquids, ultra-high speed seals, exclusion seals and sealed ferrolubricant systems (SFS).

750852. What's New with Seals? John G. Stone and John B. Scannell, Parker Seal Group, Parker-Hannifin Corp.

In the last few years a great many changes and improvements have taken place in the technology of the sealing industry, particularly with regard to those seals which utilize elastomers to do the job. This sealing technology can be divided into three primary areas: materials, designs and testing procedures.

In the material area, there have been a number of significant improvements in some of the older polymers. There have also been several new materials, both in the thermoset and thermoplastic varieties which have enjoyed substantial success.

A great deal of emphasis has been placed on the development of superior exclusion devices. Also, a number of new improved packings have permitted operation at higher pressures and broader temperature ranges than was previously possible.

A very significant development has been the formalization of a number of industry standards for the evaluation of these sealing devices. For the first time, it will be feasible for the user to evaluate performance characteristics of seals supplied by different manufacturers using the same yardstick.

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750853. Hydraulic Reservoir Breathers: How Good. John M. Karhnak, Jr., U.S. Army Mobility Equipment Command; and Hermann Spelten, Federal Republic of Germany Armed Forces.

The U.S. Army Mobility Equipment Command is responsible for specification requirements for a number of kinds of construction equipment. In studying a newly acquired warehouse forklift truck, it was noted that the hydraulic fluid was quite clean even though the system filter was not an exceptionally good one. The vehicle manufacturer stated that a study had indicated that the air breather on the reservoir was a major ingression point for contamination. As a result, this company had equipped the vehicle with a much more efficient breather than required by the Government specification.

No reasonable breather test standard appeared to exist. Engine air cleaner tests were judged unsuitable and extremely complicated. A test was derived to simulate the oil volume change normally found in warehouse forklifts.

Breathers tested included sintered bronze, phenolic ribbon, and pleated paper elements. The test showed dramatic differences in efficiency and dirt capacity of breathers, not always related to size, cost, or "nominal" rating.

750854. Development of a High Pressure Vane Type Hydraulic Pump Test. D. A. Chirichella, R. W. Jack and E. A. Baniak, Texaco, Inc.

A small size vane type hydraulic pump test has been developed that simulates a full-scale vane pump operating at high pressures on an off-highway construction vehicle. This paper describes the design of the test rig and the selection of the operating parameters. Results obtained in both the small size and the full-scale pumps are compared. The effects of two ZNDTP type antiwear additives are included in this discussion.

750855. Significance of Used Oil Analysis for Tractor Hydraulic Fluids. J. L. Thompson and P. C. Vienna, Amoco Oil Co.

The significance of used oil analyses as applied to tractor hydraulic oils is discussed with particular emphasis on fluid commingling. Pentane insolubles and changes in

TAN or TBN are used to assess in-service oxidation stabilities of tractor transmission-hydraulic oils. Spectrographic wear-metal analyses were difficult to interpret without detailed information on unit design, maintenance and use. A base-lining technique can be helpful for evaluating wear in tractor field tests.

Estimates of fluid commingling were developed from used oil additive-metal analyses. Commingling was extensive, averaging 43% in seventeen farm tractors of various manufacture. No field problems have been identified that are caused by commingling. Our experience indicated that a common transmission-hydraulic lubricant for service fill use in all farm equipment is feasible.

750856. Hot Forged Powder Metal Rolling Bearings. John S. Adams and Douglas Glover, Federal-Mogul Corp.

This paper describes a new commercial process using hot forged powder metal for making rolling bearing rings. Parts made by this process have engineering properties equal or superior to wrought steel parts. Test results are given for hot forged powder metal tapered roller bearing cups which verify the physical characteristics and performance of rolling bearing rings produced by this process.

750857. Optimizing Transmission Bearing Selection and Assembly. R. W. Hacker and W. R. Cuming, Timken Co.

Optimizing bearing selections for transmissions requires accounting for environmental differences between laboratory conditions used in rating the bearings and actual field conditions where the bearings will be used. Assembly methods become an important part of optimizing the design.

750858. Allis-Chalmers Power Shift Transmission — A New Option for the Models 7040 and 7060 Agricultural Tractors. Joseph R. Hoepfl and Gerard M. Ballendux, Allis-Chalmers Corp.

Allis-Chalmers has introduced a new Power Shift transmission to be utilized in its New Family of agricultural tractors in the 136-161 hp (101-120 kw) class. This optional transmission, utilizing both countershaft and planetary gearing, heavy duty, wet disc clutches and a uniquely designed control system provides twelve forward and two reverse vehicle speeds when coupled with the standard range transmission. Qualities of durability, safety and low noise emission of the Models 7040 and 7060 tractors are further enhanced by smooth power shifting, providing additional operator convenience and performance.

750859. An Experimental Investigation of Two-Stroke Internal Combustion Engine Performance. R. Edward Kelsay and Donald Margolis, Dept. of Mechanical Engineering, University of California at Davis.

The relation between the power and the pressure-time history at the exhaust port of a high performance two-stroke engine is explored. Through the use of a variable length expansion chamber with five different tailpipes, the effect on power of stuffing pulse arrival time, magnitude and duration was found. The results from this set of tests are compared with those of two side exit expansion chambers and an inverted tailpipe expansion chamber.

Tests were also made to determine how mid-range torque and high speed torque effect of the performance of the motorcycle. An optimum configuration (pipe length and tail pipe length) was found for the 360 Yamaha tested.

Discussion: G. P. Blair, Queen's University of Belfast (Northern Ireland).

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750860. Modeling of Two-Stroke Internal Combustion Engine Dynamics Using the Bond Graph Technique. Donald Margolis, Dept. of Mechanical Engineering, University of California at Davis.

The important internal dynamic interactions which ultimately determine the performance of a two-stroke internal combustion engine are identified and then modeled using the bond graph modeling technique. Each of the important dynamic characteristics are developed independently, presenting both the bond graph and mathematical formulation of each of the assumed subsystems. These subsystems are assembled into the final overall system bond graph and governing state space equations are derived. The result of this development is a reasonably straightforward procedure for assembling virtually any size two-stroke ICE with virtually any internal geometry into a cogent, simulatable mathematical formulation.

The procedure outlined above is demonstrated for the Yamaha 360 MX motorcycle engine. In addition to presenting results for various internal dynamic interactions (pressure, flow, temperature, etc.), the model is shown to yield excellent predictions for power and torque as a function of RPM.

Discussion: G. P. Blair, Queen's University of Belfast (Northern Ireland).

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750861. An Investigation into Piston Ring Scuffing During Running-In. J. E. Willn and P. S. Brett, British Technical Council of the Motor and Petroleum Industries.

The investigation concerns the influence of lubricants, materials, and surface finish on scuffing failure employing a special test rig and a high speed, single cylinder, engine. The rig, which was used to gain closer control and ease of observation, reproduces characteristic scuffing and has defined a range of performance in terms of contact load, ring velocity and liner temperature. Trends in performance are found to correlate with service experience and a "performance-factor" has been derived relating median

failure loads for various speeds. Confirmation of rig results is being obtained in the engine in terms of operating conditions of ring velocity and ring contact load defined by the "performance-factor".

750862. Temporary Engine Oil Viscosity Changes at High Temperatures. G. F. Busetto, G. Capello, U. Giulio and E. Volpi, Fiat (Italy).

The work starts with the investigation of the temporary viscosity loss of engine oils (SAE Paper No. 740976) and extends to the evaluation of the temporary viscosity changes on multigrade engine oils at the crankshaft bearings of European gasoline engines.

In view of this, oil temperature is measured and a calculation is made of the distribution of shear rates and pressures acting on the lubricant film at the central crankshaft bearing of a European engine.

Then an experimental evaluation is made of the temporary viscosity changes at high temperature of a multigrade oil under the separate action of high shear rates and pressures.

A rolling-ball viscometer is used to measure the temporary viscosity of oil under pressure.

Finally, an attempt is made to draw up a balance of the temporary viscosity of a multigrade oil in the different points of the bearing under examination.

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750863. European Oils for Spark Ignition Engines. F. Roux, Institut Francais du Petrole (France).

The design and operating conditions of European gasoline engines, without being basically different from those of American engines, nonetheless have various original aspects. The special lubrication requirements resulting from this are reflected in both the composition of motor oils and in their bench testing methods.

This paper attempts to analyze the physico chemical properties and performances in gasoline engines of a few recent oils that are representative of the European market. The leading properties are : viscometric properties, ash content, elastomer compatibility, volatility, mechanical and thermal shear strength, corrosion resistance, sticking resistance, deposit formation resistance, preignition resistance, wear resistance, etc.

These experimental results are obvious scientific and technical justification for CEC test methods, including both operational ones and others being researched.

750864. Low Temperature Viscosity Requirements of the Italian Car Population. M. Belati, Essotech (Italy).

To start an internal combustion engine, the cranking speed must equal or exceed the minimum starting speed of that engine.

The viscosity requirement of an engine, at a given temperature, represents the highest value of the sump oil viscosity above which the cranking speed does not exceed the minimum starting speed. The viscosity requirement is determined by measuring the engine cranking speed versus oil viscosity and ambient temperature and determining the minimum starting speed.

The viscosity requirement of the most popular Italian passenger car engines has been determined. The results are presented in form of satisfaction curves giving the percentage of cars starting as a function of ambient temperature and oil viscosity.

The results show that even in the most severe Italian weather conditions a 20W-X oil satisfies about 92% of the car population; 98% is satisfied by a 15W-X, while a 10W-X ensures trouble free operations in practically all cars.

750865. European Practice in Respect of Automotive Cams and Followers. R. J. Love and F. C. Wykes, British Technical Council of the Motor and Petroleum Industries.

American and European practice concerning cams and followers differ appreciably, and an important feature in Europe is the diversity of materials and designs employed. Suitably applied, the information now available on cam and follower behaviour should ensure satisfactory operation in service. There are various engine tests carried out in Europe to determine cam and follower durability, and to a limited extent American methods are included. However, through "CEC", European companies are developing a method which employs a special test machine.

750866. European Valve Train Wear—Some Experience With the Volvo B20 Test. B. B. Slater, Gulf Research Laboratoria B.V. (The Netherlands).

Valve train wear performance of crankcase oils and their components has been evaluated in 20-hour Volvo 2 litre engine tests. Results show that specifying a minimum zinc level in an oil does not necessarily assure freedom from cam and tappet wear. The interference effect of the detergent inhibitor package (DI) on the functioning of the anti-wear additive is clearly demonstrated. Case studies of lubricants at performance levels ranging from API SC-CB to SE and CD highlighted the effects of viscosity index improvers (VII) oil quality variation, tappet surface treatment, effectiveness of various zinc dialkyldithiophosphate agents (ZDDP) and failure mechanisms. Test procedure investigations were conducted to evaluate the precision of the method, the effect of cycle time on the failure rate and test engine life.

750867. Hydraulically Boosted Brakes—An Important Part of Central Hydraulic Systems. Hans-Christof Klein and Hans Strien, Alfred Teves GmbH (Germany).

This paper discusses hydraulically boosted brakes and the energy primarily considered in dealing with central hydraulics. Powered system classifications and general applications for automotive power assistance are explored

as well as brake system concepts, system layouts, and component designs.

Discussion: J. W. Miller, Delco Moraine Div., General Motors Corp.

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750868. Trailer Vac—A New Hydraulic Trailer Braking System. Earl A. Sheridan and John T. Kasselmann, Automotive Control Systems Group, Bendix Corp.

The Bendix Trailer Vac brake actuation system is designed for trailers equipped with automotive hydraulic brakes. Engine manifold vacuum is the power source and trailer brakes are applied in direct proportion to the tow vehicle braking level. The Trailer Vac system is available in three sizes and is capable of braking trailers weighing from 6,000 lb. to 40,000 lb. Significant improvements in the braking performance of combination vehicles has been demonstrated. The paper describes the features, development, performance and application of these systems.

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750869. The Water-Cooled Volkswagen PCI-Stratified Charge Engine. W. R. Brandstetter, G. Decker and K. Reichel, Research and Development, Volkswagenwerk AG (West Germany).

The development of a 1600 ccm SCE with a divided combustion chamber and fuel injection into the prechamber is described. Mathematical simulation was used to study the influence of several parameters. Single and multi-cylinder engine tests were carried out to determine the most suitable fuel mass fraction for the prechamber. The effectiveness of the lean thermal reactor was measured. Vehicles were tested accordingly to the CVS-procedure. PNA emissions and octane requirements were also determined. Some limited testing was done with methanol fuel. During the test program no specific problems on components were encountered.

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750870. Design and Results of the Five-Cylinder Mercedes-Benz Diesel Engine. Kurt Oblander and Manfred Fortnagel, Daimler-Benz AG (West Germany).

This paper gives the background for the development of the five-cylinder diesel engine, introduced as a passenger car first.

It discusses the main design features of this engine, its combustion and fuel injection system, and the associated aspects of balancing. Performance, fuel economy and exhaust emissions of the engine result in very interesting vehicle features.

750871. Durability and Fuel Economy Experience with Dual Bed Catalyst System. F. M. Dunlevey and R. R. Steiner, Gould Inc.

Vehicle durability data using the Gould NOx catalyst system is presented. Two 1973 vehicles accumulated 25,000 AMA miles each demonstrating efficient and stable control of NOx, HC, and CO vehicle exhaust emissions.

In additional tests, accurate fuel economy data using a 1975 California vehicle were taken. The vehicle system was optimized such that the fuel economy was improved by 2.6% while meeting the 1978 emission standards of 3.4 gram per mile CO, 0.41 gram per mile HC, and 0.4 gram per mile NOx.

750872. Comparison of Automotive Catalytic Honeycomb Structures through Two-Dimensional Thermal Stress Analysis. Mizuho Fukuda and Kazuo Osada, Nissan Motor Co., Ltd. (Japan).

This paper describes and compares five types of catalytic structures devised for automotive honeycomb catalytic converters, all of whose honeycomb meshes vary in shape - regular triangle, regular hexagon, square, and corrugations (types A and B).

Each honeycomb structure is analyzed as a two-dimensional frame structure, and its thermal deformation and thermal stress are discussed in comparison with those of the other types.

The analytical results are examined for differences in mechanical properties, the effects of the outer cover and of the wire mesh support, the development of cracks, etc.

Further, through the use of simple experimental models, the paper describes how the analytical results have been proven to be correct.

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750873. The Thermal Performance of Automotive Disc Brakes. Rudolf Limpert, Mechanical Engineering Dept., University of Utah.

A new thermal performance measure of automotive brakes is presented which allows the design evaluation of a brake relative to its effective use of rotor material in a single stop or during continued braking. Approaches for improving thermal performance are discussed. Various temperature measurement schemes are evaluated and typical test results are presented.

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750874. Friction Materials for Small Car Solid Rotor Applications. John P. Kwolek, Automotive Control Systems Group, Bendix Corp.

Semi-metallic friction materials recently developed offer significant improvements in lining life, rotor compatability and noise over organic friction materials on small cars equipped with solid rotors. Improvements originally predicted from full brake inertia dynamometer tests have been verified on vehicle durability and fleet tests.

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750875. On and Off-Board Brake System Monitoring Status and Prospects for the Future. Thomas H. Forman and William Lemeshewsky, Systems Div., AVCO.

Automobile brakes contain friction materials which by definition will wear as the brakes are being used and require replacement to prevent failure or damage to the brake system.

In addition to the brake friction materials, the hydraulic and mechanical systems involved in brakes of automobiles deteriorate over a period of time. This deterioration occurs at a rate which requires several reiterations of repair throughout the life of the vehicle.

Wear rates change significantly depending on driving habits, vehicle design and geographic and climate conditions of use. This variation makes it difficult if not impossible to predict with any accuracy when parts of the brake system require maintenance or replacement.

In order to avoid dangerous brake failures and expensive repairs caused by deterioration, it is desirable to monitor the status of brakes. Current methods for doing this are limited.

The object of this paper is to present the present state-of-the art of monitoring passenger car brake systems and to describe how this is being accomplished by on-board sensors. A more comprehensive "off board" monitoring system which is being developed by Avco is also described.

As a result of this study, the automobile engineer will have a better understanding of the type of modifications which may be required to improve the brake-related safety aspects of automobiles and decrease brake maintenance costs.

750876. Pad Wear Indication for Disc Brakes. Peter Hattwig, Volkswagenwerk AG (West Germany).

In regard to disc brakes, it can be advantageous to indicate the wear of the pads by means of a warning device. Such a warning device should fulfill a series of requirements, which will be explained individually. All systems which are known are classified according to the type of working sequence, are described, evaluated and compared. In the Volkswagenwerk the comparison favoured a newly developed system with which the wear of the pads is perceptively perceived and which is designated as the "tactile" indicator. When the wear limit is reached, a wear resistant segment at the pad then contacts a lug which is on the disc and is approximately the same size as the segment. This contact produces a perceptible knock at the brake pedal. The oscillations, which arise, produce inertia forces which are calculated. Furthermore, the wear resistance of the pad segment and the possible effects of the oscillation on the braking ability of the vehicle are calculated.

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750878. Characteristics of Alcohol-Impaired Drivers. Arthur C. Wolfe, Highway Safety Research Institute, University of Michigan.

This paper reports on data collected in 77 local and one national roadside breathtesting surveys. Overall one eighth of the 74,677 nighttime drivers tested had BACs of 0.05% or more, and this proportion increased substantially in the early morning hours. Analysis of some characteristics of these alcohol-impaired drivers showed that they are disproportionately likely to be male, divorced, black, in their thirties, of low socio-economic status, heavy drinkers, and traveling from a bar or tavern. However, all kinds of motorists sometimes drive after excessive consumption of alcohol and auto designers should take this into account in trying to develop control systems which will minimize the chances of error by drivers who have had too much to drink.

750880. Alcohol Effect on Vigilance Performance. C. W. Erwin, E. L. Weiner, J. W. Hartwell, T. R. Truscott and M. I. Linnoila

A vigilance study utilizing visual stimuli demonstrates one of the mechanisms of alcohol effects on human performance. The number of failures to respond to critical signals increases as a function of blood alcohol level. Using appropriate physiologic monitoring, it is possible to detect periods of drowsiness with associated prolonged eyelid closures. Further insight into the mechanisms involved is gained when response failures are divided into eyes-open and eyes-closed failures. Alcohol produced a significant increase in eyes-closed (drowsy) failures but did not change eyes-open failures.

750881. Applied Photoelasticity for Engine Component Design Analysis. A. K. Goyal and E. I. Watkins, Ford Motor Co.

This paper discusses in detail three applications of photoelasticity to engine component design and failure analysis. This stress analysis technique provides whole field stress distribution and can also be used to optimize a design by obtaining even stress distribution. The applications discussed cover several aspects of photoelasticity such as two and three dimensional model analysis, stress freezing, thermal and mechanical loading simulation. These are some of the many investigations conducted by the authors and can be used as a guide to many other applications. The results of the analysis have been verified during endurance testing, but are not discussed in this paper.

750882. Calculation of a Dynamically and Eccentrically Loaded Bolted Conrod Connection According to VDI 2230. A. Grotewohl, Volkswagenwerk AG (West Germany).

The first part of this paper will examine the dependencies of the forces and moments in the joint face on working force and distribution of flexural rigidity.

In the second part calculation of the connecting rod bolted assembly is carried out with the aid of the sequence of mathematical steps recommended in VDI 2230. The calculated bending stresses have been satisfactorily confirmed by measurement at maximum bearing clearance.

In the third part the possible causes of failure of the

connecting rod are summarized. Of the five possible causes of failure— lifting in the joint face, transverse displacement at the joint face, exceeding the yield point in the bolt shank, flexural fatigue fracture in the first load bearing screw thread and plastic deformation under compressive stress— the first two are least safe with maximum tightening factor.

750883. Indiscope—A New Combustion Pressure Indicator with Washer Transducers. M. Kondo, Gakushuin University (Japan); A. Niimi and T. Nakamura, Rion Co., Ltd. (Japan).

As the New Pressure Indicator is easily installed on running cars, without altering any part of the engines in question, one can observe the real working behaviour of the engines, transient as well as steady-state, and not only in laboratories but also on open roads.

Some examples of indicator diagrams, unfamiliar and unexpected as well as normal, and also the interesting sequence of them, are shown.

750884. Correction Factor to Unit Core Heat Transfer Capability of Heat Exchanger Core Due to Variation of Tube Length. Jiunn P. Chiou, Mechanical Engineering, University of Detroit.

In the design and selection of heat exchangers, three basic methods are used; namely Log Mean Temperature Difference Method, e-NTU Method or the Unit Core Heat Transfer Capability Method. In the preliminary analyses of heat exchanger core in automobile industry, the 3rd design method is generally used. The 3rd method relies on the correlation data between unit core heat transfer capability and air flow velocity in front of the core. These correlation data are usually obtained in wind tunnel using 12″ × 12″ or 6″ × 6″ basic core. When the tube length is different from the basic core length, correction of the heat transfer performance of the core should be made.

This paper presents a mathematical formulation of this correction factor. These correction factors are also presented in several graphs and tables using water, 50/50 aqueous ethylene glycol solution, engine oil and hydraulic fluid as the hot side fluid. These correction factors are needed in engineering analyses of various coolers and radiators in automobile cooling system.

750885. Turbulent Flow in Spark Ignition Engine Combustion Chambers. E. H. James and G. G. Lucas, Loughborough University of Technology (United Kingdom).

The development of a hot wire anemometry system to study the turbulent flow conditions in spark ignition engine combustion chambers is described. Measurements of a 'mean' flow velocity and a fluctuating flow velocity within certain frequency bandpass ranges are reported under 'motoring' engine conditions during the 'combustion period' of the engine cycle. Two types of combustion chamber design have been investigated - a 'squish' design and a cylindrical disc design.

750886. The Measurement of the Turbulence Characteristics in an Internal Combustion Engine Cylinder. J. C. Dent and N. S. Salama, Dept. of Mechanical Engineering, Loughborough University of Technology (United Kingdom).

A method has been presented for the determination of the turbulence characteristics in engine cylinders using hot wire anemometry, and high speed random signal data processing techniques.

Results obtained on two engines show agreement with the findings of other workers.

Data for Micro and Macro-scales of Turbulence are presented for the first time, and evidence put forward to suggest very weak dependence of the Microtime Scale λ_t with either engine speed or combustion chamber geometry.

750887. A Laser Interferometer Study of Combustion Near an Ignition Source in a Static Chamber. Keshav S. Varde, University of Michigan-Dearborn.

Operation of spark ignition engine under lean mixture condition is one of the several options that may be used to meet pollution and fuel economy standards. In such an operation various factors influence the combustion phenomenon. To examine these, a study is conducted in a static chamber using lean propane air mixtures of different stoichiometry. Effects of ignition energy, electrode geometry, location of ignition source and temperature profile in the initial reaction zone are investigated.

It was found that increasing ignition energy accelerated flame up to a certain point; any futher increase in energy had little effect on the flame acceleration. The rate of pressure rise also showed a similar pattern. Temperature in the reaction zone was lower when the ignition point was near the wall than away from it; the temperature profile was mapped using laser interferometer techniques. Round tipped electrodes showed better repeatability and yielded lower ignition energy than the flat tipped.

750888. Combustion and Exhaust Emission of an Engine Using the Porsche-Stratified-Charge-Chamber-System. Dusan Gruden, Porsche (West Germany).

The development of vehicle combustion engines today is characterized by the effort to reduce exhaust gas emission and fuel consumption and to conserve the good properties of the combustion engine at the same time. As, at least for the years to come, there will be no chance for the utilization of the alternative special drives, PORSCHE is intensely dealing with the further development of the conventional combustion engine as well as of the stratified-charge-chamber engine. With their stratified-charge engine (SKS) PORSCHE has tried to create optimum conditions for each of the combustion phases. The result

was a divided combustion chamber with a three-stage combustion. The system was tried on single-, six-, and eight-cylinder engines and led to good results under stationary conditions on the testing rig as well as under unstationary driving conditions.

750889. The Staged Combustion Compound Engine (SCCE): Exhaust Emissions and Fuel Economy Potential. Robert M. Siewert and Stephen R. Turns, Research Laboratories, General Motors Corp.

A staged combustion engine has been evaluated in which pairs of cylinders are coupled in series. The first cylinder of the pair inducts and burns a homogeneous, fuel-rich mixture which produces exhaust products containing substantial amounts of combustibles (CO, H_2, and HC) and only small quantities of NO_x. These products are then cooled, mixed with additional air, and inducted into another cylinder for a second stage of combustion. Additional work is extracted in this second stage, where substantial cleanup of CO and HC occurs while maintaining a low level of NO_x.

Experiments with a two-cylinder research engine showed that low NO_x emission could be obtained without sacrificing engine efficiency. However, approximately 40% more displacement is required to produce the same power as conventional SI engines. The sources of HC, CO, and NO_x emissions were investigated, as were the effects of major engine variables on these exhaust emissions and fuel consumption.

The staged combustion concept was implemented using a 7.46 litre V-8 engine, for which the necessary control systems were devised and built. This engine was evaluated in an experimental vehicle on a chassis dynamometer with a 2041 kg (4500 lb) inertia weight. Present FTP emission levels are 0.87 g/mi HC, 8.7 g/mi CO, and 0.34 g/mi NO_x at low mileage using a catalytic converter. FTP fuel economy is 4.9 km/l (11.5 mpg), but acceleration performance is poorer than comparable production cars. Adequate evaluations of production-related factors such as driveability, durability, and fuel requirements have not been made. Although the low NO_x emission demonstrated by this engine concept is noteworthy, the engine is presently precluded from serious contention by the stringent limitations which current statutes place on allowable HC and CO emissions during the 1975 FTP.

Discussion: Alok Goyle, O. A. Vyehara and P. S. Myers, University of Wisconsin.

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750890. High Chemical Activity of Incomplete Combustion Products and a Method of Prechamber Torch Ignition for Avalanche Activation of Combustion in Internal Combustion Engines. L. A. Gussak, Institute of Chemical Physics Academy of Sciences of the USSR, Moscow.

Aside from the stable products of combustion (CO_2 and H_2O) and some incomplete constituents (CO, H_2, and others) in the flame front of a hydrocarbon-air mixture, there are also formed various concentrations of components of intermediate chemical reactions. Studies in cyclic and stationary flames of the kinetic formation, heat and temperature of catalytic recombination of these components, establish the unusually high concentration of ionized atoms and radicals (H, CH, C_2, and others) in the branching chain reactions which can exceed the thermodynamic equilibrium by an order of two to four. These are formed in the flame of a rich mixture possessing a 30 to 60% insufficiency of air. The ionized atoms and radicals are short-lived but can initiate specific chemical activity during their life span of 5 to 10 ms. The concentrations of these reactive elements sharply diminish as the rich mixture is leaned toward stoichiometric.

An analysis of the hydrodynamical structure in the combustion zone, which is initiated by the burned products of combustion fed from an auxiliary combustion chamber, led to the discovery of a means to develop turbulent vortex kernels in the wake of the prechamber torch to achieve rapid and efficient combustion. Optimization is achieved by employing a prechamber volume of 2 to 3% of the compressed combustion chamber volume, employing connecting channels with an area of 0.03 to 0.04 cm^2 per 1 cm^3 of the prechamber volume and employing channels with a length to diameter ratio of 1/2.

Out of this research work has evolved the "LAG-Process" of combustion which utilizes the high chemical activity of the products of incomplete combustion of a rich auxiliary mixture to produce fast, complete, and stable combustion in the working main mixture within the combustion chamber of various types of engines. The delay period of ignition of the main mixture is decreased by 5 to 7 times and the combustion duration is significantly decreased by 3 to 4 times in comparison to spark ignition. A 10% improvement in combustion efficiency is achieved and the overall combustion becomes exceptionally stable and reproducible.

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750891. An Historical Overview of Research in Traffic Accident Investigation Activities. Jack D. Baird and Eugene E. Flamboe, Institute of Safety and Systems Management, University of Southern California.

Two previous reviews of the research aspects of traffic accident investigations are used as starting points for presenting an up-date of accident investigation activities, both in the U.S. and in foreign countries. Elements of national accident investigation programs are discussed as well as areas of current accident investigation technology. An international accident investigation feasibility study under the auspice of NATO is also studied.

750892. A Discussion of Data Gathering Systems. Edwin A. Kidd, Calspan Corp.

This paper discusses a data sampling plan that provides an

accident data file representative of the national population. It is a system for data processing, storage, and retrieval to allow early determination of trends in accident, injury, and fatality frequencies. The system of data collection discussed lies somewhere between the very detailed team approach and the routine police reporting as established independently by the states.

750893. A Comparison of Results Obtained With Different Analytical Techniques for Reconstruction of Highway Accidents. Raymond R. McHenry, Transportation Safety Dept., Calspan Corp.

For several staged collisions, results obtained with closed form reconstruction calculations and with a computerized step-by-step procedure are compared with measured responses. A refined, closed-form reconstruction procedure is defined, derivations of the analytical relationships are outlined and detailed results of sample applications are presented.

Closed form calculation procedures for estimating impact conditions became a topic of interest in relation to the development of an automatic starting routine for iterative applications of the Simulation Model of Automobile Collisions (SMAC) computer program. The accuracy of initial estimates of speeds determines the total number of iterative adjustments of SMAC that are required to achieve an acceptable overall match of the evidence. Since a high degree of success was achieved in the refinement of such calculation procedures, the end product, by itself, is considered to be a valuable aid to accident investigations.

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750894. Automated Accident Reconstruction. Ian S. Jones, Transportation Safety Dept., Calspan Corp.

The Simulation Model of Automobile Collisions (SMAC) computer program was developed by Calspan Corporation as an aid with which to accurately reconstruct road accidents. Part of the overall objective of the research has been to make the system "user oriented" so that users without an engineering background can operate it with ease. This has necessitated developing a START program which automatically runs the SMAC program from a minimum of input data and an iteration routine designed to optimize the input values of velocities to provide a "best fit" reconstruction to the available scene data.

A summary of how the START program works is given; however, emphasis is placed in the paper on the development of the iterative routine. The theory behind the routine is given and a number of examples are then presented to show how it works. For each example the results of each successive iteration are given to illustrate the manner in which the program converges to an acceptable reconstruction.

750895. Analysis of Automobile Collisions. Bharat Bhushan, Automotive Specialists.

Expert investigators are required to reconstruct the accidents involving the collision of automobiles, or of an automobile hitting a stationary obstacle or both, based on post-accident information. Post-accident information normally includes the damage of the automobiles due to the collision, the skid marks, the damage due to the obstacle, and the distance travelled by the automobiles after impact. The general transient analysis of automobile collisions, discussed in the paper, includes relative sliding, rotation, and plastic deformation of the automobiles. Experimental methods are described to obtain the automobile parameters, that is center of gravity and moment of inertia. An approximate general analysis is proposed to estimate the energy lost in relative sliding and plastic deformation during impact. The movements of the occupants of the automobiles during impact are described. Simplifications can occur depending on the nature of the accident. The general analysis is specialized for these simplifications. Based on the author's experience, some examples are given to illustrate the theory.

750898. Human Factors/Ergonomic Aspects of Vehicular Accident Investigation 1975 Update. Fred L. Sublett and William T. Roe, Institute of Safety and Systems Management, University of Southern California.

This paper presents a case for the growing application of Human Factors/Ergonomic expertise to develop decisions that take place within the transportation industry. It offers a definition of the HF/ERG engineering in traffic safety, research, training, and education.

750899. Comparison of Oil Economy in Large and Small Passenger Car Engines. Robert J. Main and Robert W. Scher, Lubrizol Corporation.

A study was undertaken to compare the oil consumption characteristics of large and small automobile engines. A fleet of 120 employee-owned vehicles was operated in typical passenger car service in the Cleveland, Ohio area between April and December, 1974. Two test oils of equal viscosity but widely varying volatility characteristics were used for the study.

The results showed no correlation between engine size and oil consumption. The results also showed no difference in oil consumption between the test oils. The results did show the expected trent toward higher oil consumption with increasing engine mileage. The development of a standardized laboratory procedure which correlates with oil consumption in passenger cars is recommended.

750900. Deposits, Wear, and Catalyst Performance with Low Ash and Ashless Engine Oils. Loren G. Pless, Research Laboratories, General Motors Corp.

To meet exhaust emission standards, nearly all 1975 model U.S. passenger cars use catalytic converters in conjunction with unleaded gasoline. While it has been established that lead and phosphorus from gasoline are

deleterious to catalyst performance, much less is known about any similar effect of elements normally present in conventional engine oils. In addition, the ability to protect engines from excessive deposits and wear is essentially unproved for engine oils in which the phosphorus and metals contents have been either reduced (low ash oils) or eliminated (ashless oils).

To obtain catalyst and engine performance information on such oils, tests were run using 95, 1972-1973 model passenger cars, operated with unleaded gasoline in several types of service. Forty cars were equipped with 1975 production-prototype underfloor catalytic converters containing pelleted oxidation catalysts.

Neither exhaust emissions nor catalyst conversion efficiency were affected by using either a low ash or an ashless oil instead of a conventional oil. However, oil consumption was less than typical for such service, so the effect of oil additives on catalyst durability may have been proportionately less.

Five experimental ashless oils were all deficient in engine performance in varying degrees, compared to conventional commercial SE-quality oils, with respect to cam and lifter wear, oil ring sticking, and piston varnish deposits.

It is concluded that reduction in phosphorus or metals content of current, conventional, commercial oils does not appear to be necessary to meet current exhaust emission standards with current General Motors (GM) catalyst systems. However, development of ashless oil technology should continue in the event such oils are necessary to meet future, more stringent engine or emission requirements.

Discussion: R. D. Robins, Lubrizol Corp.; and W. C. Long, Chevron Research Co.

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750901. Exhaust Emissions from Heavy-Duty Trucks Tested on a Road Course and by Dynamometer. Gordon J. Kennedy and John T. White III, U.S. Environmental Protection Agency; Karl J. Springer and Melvin N. Ingalls, Southwest Research Institute.

This is a summary compilation and analysis of exhaust-emission results and operating parameters from forty-five heavy-duty gasoline and diesel-powered vehicles tested over a 7.24-mile road course known as the San Antonio Road Route (SARR); and, for correlative purposes, on a chassis dynamometer.

Exhaust samples were collected and analyzed using the Constant Volume Sampler (CVS) technique similar to that used in emission testing of light-duty vehicles. On the road course, all equipment and instrumentation were located on the vehicle while electrical power was supplied by a trailer-mounted generator. In addition to exhaust emissions, operating parameters such as vehicle speed, engine speed, manifold vacuum, and transmission gear were simultaneously measured and recorded on magnetic tape.

The forty-five vehicles tested represent various model years, GVW ratings, and engine types and sizes. The testing was performed under several EPA contracts with Southwest Research Institute during the years 1972 through 1975.

This paper summarizes results from the road-route tests and the chassis-dynamometer tests, and makes comparisons between these two test procedures.

750902. Application of Heavy-Duty Catalytic Converters on Medium and Heavy-Duty Gasoline Powered Trucks. T. V. De Palma and C. H. Bailey, Automotive Products Div., Universal Oil Products Co.

This paper discusses the use of an oxidation type catalytic converter for medium and heavy-duty gasoline powered trucks. It offers the highest reductions of HC and CO; and it is the simplest, most durable, and most cost effective system for reducing air pollution from trucks without fuel or driveability penalties.

750903. Emissions Control of Gasoline Engines for Heavy-Duty Vehicles. Charles M. Urban and Karl J. Springer, Southwest Research Institute; and John J. McFadden, U.S. Environmental Protection Agency.

This paper summarizes an investigation of reductions in exhaust emission levels attainable using various techniques appropriate to gasoline engines used in vehicles over 14,000 lb GVW. Of the eight gasoline engines investigated, two were evaluated parametrically resulting in an oxidation and reduction catalyst "best combination" configuration. Four of the engines were evaluated in an EGR plus oxidation catalyst configuration, and two involved only baseline tests. Test procedures used in evaluating the six "best combination" configurations include: three engine emission test procedures using an engine dynamometer, a determination of vehicle driveability, and two vehicle emission test procedures using a chassis dynamometer. Dramatic reductions in emissions were attained with the catalyst "best combination" configurations. Engine durability, however, was not investigated.

750904. The Use of Constant Volume Sampler and Dilution Tunnel to Compare the Total Particulates from a Range of Automotive Engines. D. Collins, R. D. Cuthbertson, R. W. Gawen and R. W. Wheeler, Ricardo Consulting Engineers.

The development of a simple CVS particulate test and its application to various engine types is shown to quantify a number of problem areas.

Research into the reduction of particulates in exhaust gases can be carried out more effectively by this technique than by the older optical methods.

These investigations, however, lag far behind those into the better known gaseous emissions.

750905. Control of Refueling Emissions with an Activated Carbon Canister on the Vehicle. J. A. Gunderson, Olson Laboratories, Inc.; and D. K. Lawrence, Amoco Oil Co.

This report documents the investigation of the technical and economic feasibility of using a carbon canister on board the vehicle to retain displaced hydrocarbon vapors during refueling. Denoted by the API as an Interim Report of Project EF-14, this report is a sequel to the Project's Phase I Report of April 1973, "Cost Effectiveness of Methods to Control Vehicle Refueling Emissions."

To initiate the design of a prototype carbon canister system capable of handling refueling vapor losses, studies were undertaken on a bench-test system to define the total amount of refueling vapor to be handled, vapor retention capacity of activated carbon, and purge capacity over a range of refueling conditions and fuel system parameters. In addition, extensive exhaust and evaporative emission tests were performed on the baseline vehicle and the modified vehicle. Detailed cost and effectiveness analyses were performed.

The study shows that this type of control is technically feasible for refueling and evaporative emissions, fuel savings can approach the cost of the refueling control system, driveability was not impaired, and exhaust CO emissions increased.

750907. Development of Simulation System for Motorcycles Using Chassis Dynamometer. Takayoshi Mabuchi, Yamaha Motor Co., Ltd. (Japan).

This report describes a new type of simulation system - automatic operation equipment for motorcycles.

In this system, all operations such as throttle, clutch and gear shifting are controlled automatically with command signals. This system could be used for the emission measurement standard modes and actual drive patterns. Therefore, this system could be used for various motorcycle simulation testing on a chassis dynamometer. Further, durability tests for emission reduction devices could be performed with reliable and effective results using this system.

750908. Characteristics of 2-Stroke Motorcycle Exhaust HC Emission and Effects of Air-Fuel Ratio and Ignition Timing. Katsuhiko Tsuchiya and Seiji Hirano

This paper discusses the results of studies of the exhaust HC emission of 2-stroke engines for motorcycles.

The major factor producing HC emissions from 2-stroke engines is the short circuiting of fresh charge. Therefore, we made a study of the relation between the delivery ratio and the trapping efficiency by comparing the test results and the theoretical values of perfect mixing. We then verified the effects of engine speeds and irregular combustion to the trapping efficiency.

Tests were conducted to clarify the relationship between the air/fuel ratio and HC concentration and mass HC emission, and the test results were compared with the theoretical values. In addition, a study was made on how to reduce the mass HC emission by optimizing air/fuel ratio.

Next, we launched tests to study the effects of ignition timing on HC emissions as well as the ignition timing characteristics and throttle opening and engine speed.

750910. Catalytic Control of Two-Stroke Motorcycle Exhaust Emissions. J. J. Mooney, J. G. Hansel and R. D. Hoyer, Engelhard Industries Div., Engelhard Minerals & Chemicals Corp.

In contrast to motorcycles with 4-stroke engines, 2-stroke engine motorcycles produce very high hydrocarbon and carbon monoxide emissions. Compared to a 1976 automobile, such motorcycles produce as much hydrocarbon emissions as ten to twenty passenger cars. Modified automobile catalyst technology with the addition of an air pump is shown to be effective in reducing the hydrocarbon and carbon monoxide emissions by 75–85% after mileage accumulation of 12,000 miles; these tests are in progress and are being continued. In spite of the fact that current 2-stroke engine motorcycles run rich (no excess air) hydrocarbon emissions can be reduced by 35% and higher with aged catalyst systems without the addition of air. The mechanical durability of the catalytic systems is completely satisfactory.

Present data indicate that catalyst system technology has been developed to meet proposed interim EPA emission standards for 2-stroke motorcycle engines. Purification of exhaust emissions for 4-stroke motorcycle engines to ultimately meet more stringent standards will be a much less formidable task than for 2-stroke motorcycle engines.

750911. STX™ Sheets — A Family of Glass Reinforced Engineering Polymer Materials. L. A. Dunning, Allied Chemical Corp. Fibers Div.

In the past 10 years a major new thermoplastics process has developed--plastics stamping. Stamping of plastics materials is not a new process, and it has developed from a simple idea: to use sheet metal processes and equipment to convert plastic sheets into parts of the right performance at the right price. This paper reviews STX stampable sheets, the part conversion processes, and some potential uses in the automotive industry.

750912. Chevrolet Monza Front End Retainer: A Case Study of AZDEL Applications. R. D. Margolis, G.R.T.L. Co.

This paper discusses aspects of thermoplastic stamping as a viable economic process in the manufacture of automotive components, particularly the Chevrolet Monza Front End Retainer. This component represents a significant commercial reality for thermoplastic stamping in a high volume, structural application.

750914. Occupant Injury Assessment Criteria. John W.

Melvin, Dinesh Mohan and Richard L. Stalnaker, Highway Safety Research Institute, University of Michigan.

This paper is a brief review of the complex subject of human injury mechanisms and impact tolerance. Automotive accident-related injury patterns are briefly described and the status of knowledge in the biomechanics of trauma of the head, neck, chest, abdomen and extremities is discussed.

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750916. A Critical Analysis of Traffic Accident Data. J. Robert Cromack and George M. Barnwell, Southwest Research Institute.

General agreement exists that the ultimate goals of traffic accident research are to reduce fatality, mitigate injury and decrease economic loss to society. Although massive quantities of data have been collected in local, national and international programs, attempts by analysts to use these data to explore ideas or support hypotheses have been met by a variety of problems. Specifically, the coded variables in the different files are not consistent and little information on accident etiology is collected. Examples of the inadequacies of present data in terms of the collected and coded variables are shown.

The vehicular, environmental and human (consisting of human factors and injury factors) variables are disproportionately represented in most existing data files in terms of recognized statistical evidence of accident causation. A systems approach is needed to identify critical, currently neglected variables and develop units of measurement and data collection procedures. The systems view would be based on the paradigm of the human operator in a man-machine system, simultaneously performing tracking and vigilance tasks and making decisions in a varying environment.

By increasing utilization of more sophisticated mathematical models of man-machine systems and controlled laboratory experiments, sets of critical variables could be defined and their interactions studied, both theoretically and experimentally. From these studies variables could be defined and hypotheses established for future field testing in traffic accident data collection and analysis programs, thereby more efficiently and effectively satisfying the original ultimate goals of traffic accident research.

750918. Evaluating Crashworthiness with AIS and CDC. L. Glen Watson and A. Carl Shiels, Transportation Centre, University of Saskatchewan (Canada).

This paper discusses the use of Linear and Nonlinear Curve Fitting Programs for the development of injury-prediction equations for automobile side and rear collisions. The data used are from the C.P.I.R. files at H.S.R.I. Separate equations developed for unrestrained, lap belt restrained and three-point harness restrained front seat occupants are discussed and compared.

750922. Vehicle Damage and Crashworthiness Data for 1973 Intermediate-Size Cars. Sol Davis and Richard W. Carr, The Dynamic Science Div., Ultrasystems, Inc.

A series of front, side, and rear impact tests was conducted by Dynamic Science, under NHTSA contract, to obtain vehicle damage and occupant crashworthiness data on two representative 1973 intermediate-size sedans. Selected evaluation variables included cost-to-repair data in dollars and crashworthiness data in terms of occupant response per FMVSS 208. The data are presented as a function of impact speed to emphasize that future vehicle evaluations must consider a broad speed range.

Since only one test was conducted for each crash condition, data are not identified by vehicle model to avoid any inferences on relative vehicle standings. Additional tests are needed, under identical conditions, to determine if differences between vehicles are statistically significant. However, these data can serve as benchmarks against which future improvements in vehicle damageability and occupant crashworthiness can be measured.

750924. A New Five-Speed Manual Transmission For Passenger Cars. Merle Dalton Coy, Warner Gear Div., Borg-Warner Corp.

This article outlines the design objectives for a light weight economical five-speed manual transmission for the subcompact, compact, and intermediate size passenger cars. Major features presented are a die cast case design allowing assembly of gears through rear opening, internal linkage, use of needle bearings and an overdrive cruising gear.

750925. An Evaluation of Manganese as an Antiknock in Unleaded Gasoline. J. E. Faggan, J. D. Bailie, E. A. Desmond and D. L. Lenane, Ethyl Corporation.

MMT (methylcyclopentadienyl manganese tricarbonyl) is an antiknock additive for unleaded gasoline, which is now required for cars equipped with catalytic converters. Because of its effectiveness, MMT is economically attractive compared with achieving antiknock quality by refinery processing.

Use of MMT in gasoline at a concentration of 0.125 gram of contained manganese per gallon provides, on the average, about 2 road octane numbers. Compared to processing, this could represent a savings in crude oil of about 1%. Like other antiknocks, the economic attractiveness of MMT is greatest at low concentrations.

Extensive road and dynamometer engine tests have shown that use of MMT in the recommended concentration range is compatible with general aspects of car operation--octane number requirement, exhaust valve and spark plug durability, and exhaust gas recycle for NO_x control. Moreover, beneficial effects in exhaust valve guide and seat wear have been observed with MMT in some tests.

In tests using cars operated on the 50,000-mile EPA certification schedule, the use of MMT had no significant adverse effect on emissions as compared to unleaded gasoline. Other tests have shown a decrease in exhausted polynuclear aromatics through the use of MMT.

MMT does not lessen the effectiveness of exhaust catalysts in oxidizing unburned hydrocarbons and carbon monoxide. Some plugging of monolithic exhaust catalysts has occurred when cars on the road are operated under conditions subjecting the catalyst to severe stresses. However, rapid catalyst deterioration has been observed under these conditions whether or not manganese is present. No catalyst plugging has been observed with MMT in more typical driving conditions.

The manganese in MMT is converted to Mn_3O_4 in the exhaust. We estimate that the median airborne manganese concentration in urban areas from widespread use of MMT would be 0.05 microgram per cubic meter; in freeway situations, estimated concentrations would be generally less than 1 microgram per cubic meter, rising above this level only under the most unfavorable meteorological conditions.

Discussion: R. Y. Heisler, Research & Technical Dept., Texaco, Inc.

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750926. The Environmental Implications of Manganese as an Alternate Antiknock. John B. Moran, U.S. Environmental Protection Agency.

Methylcyclopentadienylmanganese tricarbonyl (MMT) while originally marketed in the late 50's and early 60's as a secondary antiknock to leaded fuels, is presently being marketed as a primary antiknock targeted for the EPA required lead-free gasoline grade tailored for use in catalyst-equipped vehicles. This paper reviews and discusses new information related to the effect of manganese gasoline additives on the performance of catalysts, regulated emissions, and several currently unregulated emissions. In addition, estimates of human exposures to automotive-generated manganese particulate and the toxicological characteristics of manganese are discussed as they related to an assessment of the potential public health consequences should manganese additives come into widespread use. EPA's position regarding the use of manganese additives is presented and discussed.

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750927. Toxicologic Evaluations of Fuel Additive–Methylcyclopentadienyl Manganese Tricarbonyl (MMT). W. Moore, J. F. Stara, D. Hysell, M. Malanchuk and J. Burkart, National Environmental Research Center, U.S. Environmental Protection Agency; and R. Hinners, National Environmental Research Center, U.S. Environmnetal Protection Agency.

This paper presents data, from laboratory animals, on the toxicity and metabolic fate of the fuel additive methylcyclopentadienyl manganese tricarbonyl (MMT) and the biological effects following exposure to automotive exhaust emissions generated from an engine system which was run on a fuel containing MMT.

The Environmental Toxicology Research Laboratory has been interested in MMT because of the potential widespread use of this additive as a replacement for tetraethyl lead as an octane improver.

750929. An Evaluation of Alternative Power Sources for Low-Emission Automobiles. John W. Bjerklie, Hague International; Elton J. Cairns, Argonne National Laboratory; Charles W. Tobias, University of California at Berkeley; and David Gordon Wilson, Massachusetts Institute of Technology.

Two successive surveys and round-robin interviews were conducted to determine if there might be in the offing for automobiles an alternative engine which would exhibit low emissions meeting the most stringent requirements. Comparison between engines were couched in terms of selected "acceptability factors" which went well beyond emissions, alone. The overall acceptability was evaluated considering emissions, customer requirements for an engine, manufacturers' requirements for an engine, and engine efficiency and fuel versatility. An attempt was made to establish a time scale as to R and D requirements and eventual production. Comparison of all engines was made with equivalent pre-control Otto cycle engines as the standard.

Alternative engines were deemed to be any power plant that was not based on spark ignition Otto cycle engines, or diesel engines. The remaining heat engines largely used continuous combustion as the heat source. Electrical power plants considered were batteries and fuel cells. Hybrid engines and fuel-less stored energy power plants were given some consideration.

The unsettled nature of the present socioeconomic structure precluded singling out any particular engine or power plant most suitable for development. Evaluations of the characteristics, comparison with pre-control spark ignition engines, problems yet to be solved, and the most optimistic time schedule to be anticipated are attempted and reported. Best probable candidate power plants are then enumerated.

Keeping in mind that the future will require lowered emissions in urban air and improved efficiency of the overall transportation system, comment is made on the use of engines and automobiles. Methods of accomplishing in part the goals of the clean air act with changes in structure of the transportation system, taxes, and urban areas are suggested only as means of illustrating that low-emission engines are only one part of the overall problem of maintaining clean air and viable urban centers.

750930. Lean Burn Engine Concepts—Emissions and Economy. James E. A. John, Mechanical En-

gineering Dept., University of Toledo.
This paper discusses lean burn engine concepts for meeting emission standards features versus the use of an oxidizing catalytic converter for HC and CO control. Purely theoretical considerations indicate that thermal efficiency and therefore fuel economy should be improved by lean operation. Whether this system will be used is dependent on the Federally regulated auto emissions standards.

750931. The Diesel as an Alternative Automobile Engine. Naeim A. Henein, Wayne State University.
An evaluation has been made of the use of the diesel as an alternative engine in passenger cars. This includes the technological feasibility for meeting the different emission standards and the techniques for emission control. The emissions studied include both the presently regulated species--hydrocarbons, carbon monoxide, and nitrogen oxides--and the following nonregulated emissions: aldehydes, ammonia, smoke and particulates, polynuclear aromatics, and sulfur compounds.

A comparison has been made between the emissions, performance and economy of currently produced diesel powered cars and gasoline powered cars. Other cars which are being developed and powered by the stratified charge, Wankel, and the gas turbine engines are also included in the comparison. Intrinsic problem areas in the diesel engine that need further research are also identified and discussed.

750932. Some Observations of Factors Affecting ORI. H. E. Alquist, G. E. Holman and D. B. Wimmer, Research and Development Div., Phillips Petroleum Co.
A review has been made of anomalies that exist in the changes in octane requirement of recent model cars operated for several thousand miles using unleaded gasolines and SE quality oils. A number of laboratory multicylinder engine tests have been conducted to elucidate possible reasons for some of these anomalies. These tests have uncovered mechanical variables that can produce relatively rapid changes in the octane requirement of an engine and octane requirement differences between engines of the same make and model, operated on identical combinations of gasoline and oil. Two of the more important variables are the initial octane requirement and the amount of oil migrating to individual cylinders in the engine.

Discussion: W. H. Machleder, Rohm & Haas.

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750933. Some Factors Which Affect Octane Requirement Increase. Jack D. Benson, Fuels and Lubricants Dept., General Motors Research Laboratories.
The influence of selected engine oil, fuel, and driving schedule variables on combustion chamber deposits and octane requirement increase (ORI) has been investigated during vehicle fleet tests with late model cars.

Greater octane requirement increases occurred with: (a) an engine oil containing bright stock compared to an engine oil without bright stock, (b) an unleaded fuel which contained a polymeric detergent-dispersant additive with a large amount of carrier oil, compared to other unleaded fuels with conventional additive packages, and (c) customer-type driving compared to rapid mileage accumulation on a chassis dynamometer. Octane requirement increase was not affected by: (a) lead content of the fuel; or (b) ashless engine oil compared to a conventional ash-containing oil.

All of the ORI with unleaded fuel can be eliminated by removing the combustion chamber deposits, and about two-thirds of the ORI is caused by deposit accumulation in the end-gas region of the chamber. In late model cars using unleaded fuel, about ten percent of the ORI is due to the volume effect of deposits and the other 90 percent is probably due to thermal effects.

Discussion: W. H. Machleder, Rohm & Haas.

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750934. Octane Number Requirement Trends—Passenger Cars in U.S., 1965–1974. D. P. Barnard, Standard Oil Co. (Ohio); J. D. Rogers, Jr., E. I. duPont de Nemours & Co., Inc.; and W. L. Wascher, Mobil Research & Development Corp.
Annually, the Coordinating Research Council (CRC) sponsors a nationwide survey of octane number requirements for current model passenger cars. In this review, based on surveys from 1965 through 1974, trends in octane number requirements reflect changes in engine design and exhaust systems to meet the legislated limits on emissions.

The average requirement dropped approximately 5.5 Research octane numbers over the ten-year period with the most dramatic drop of approximately 3.0 octane numbers in 1971 when car manufacturers recommended use of 91 octane gasoline. The trends toward lower average requirements since 1971 have been determined with both leaded and unleaded fuels. Incidence of surface ignition knock and rumble was about one per cent in 1965 and tended to disappear after 1971. The average spread of octane number requirements between 10 and 90 per cent of cars satisfied increased about 2.5 numbers over the period.

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750935. The Relationship Between Octane Quality and Octane Requirement. A. G. Bell, Thornton Research Centre, Shell Research Ltd. (United Kingdom).
The paper describes the use of Road octane number equations to predict the antiknock performance of motor gasoline under a wide variety of operating conditions. It then goes on to describe how reference fuels can be used to determine the octane requirement of engines in terms of Research octane number, Motor octane number and front-end quality and how the information can be used to

calculate what proportion of any given market will be satisfied by gasolines of known inspection properties.

Brief mention is also made of the relationship between calculated values of car satisfaction and observed levels of customer satisfaction and the effects of lead, aromatics and olefins on road antiknock performance.

Future octane quality is discussed and the need for close co-operation between the oil industry, the motor industry and the legislators is identified.

750936. Advantages of Lead in Gasolines for European Cars— The Lead Road Bonus. D. D. Hornbeck, R. M. Labruyere, L. E. Stinson and G. H. Unzelman, Ethyl International.

In recent years, several programs have been conducted at the Ethyl Research Laboratories in Detroit, some in cooperation with a major oil company, to measure the value of lead antiknocks in fuels for European cars. These heretofore unpublished studies show:

1. A positive lead road bonus.
2. Tetramethyllead (TML) is more effective than tetraethyllead (TEL).
3. The lead road bonus increases with engine operating severity.

The lead road bonus is defined in broad terms as a combination of three effects—lead-in-fuel, fuel sensitivity, and engine deposits. The engine-deposit effect is not of major significance in European cars.

Much of the confusion over the value of lead antiknocks in European cars and fuels in recent years can be attributed to improper definition of the lead road bonus, at times coupled with inappropriate rating conditions and limitations in fuel design.

The importance of these studies is significant in view of the trend toward smaller cars.

750937. Octane Number Increase of Military Vehicles Operating on Unleaded Gasoline. J. D. Tosh and J. T. Gray, U.S. Army Fuels and Lubricants Research Laboratory, Southwest Research Institute; and E. B. Trescott, U.S. Army Materiel Command.

The suitability of using unleaded gasoline in military and commercially designed equipment located at four Army installations has been evaluated over a two-year period. A total of 3007 vehicles were monitored during the evaluation for maintenance and performance problems. This paper presents information on vehicle octane number requirements and octane number increase trends measured on a selected group of vehicles during the evaluation period. Details of the fuels used, vehicles tested, test procedure and results are discussed.

750938. The Use of Combustion Deposit Analysis for Studying Lubricant-Induced ORI. H. E. Bachman, PARAMINS Technology Div., Exxon Chemical Co.; and E. B. Prestridge, Analytical and Information Div., Exxon Research and Engineering Co.

This is a progress report of a continuing program aimed at understanding the role of the engine oil viscosity index improver (VII) in ORI. In this study two polymers, one hydrocarbon, one ester, have been examined in a closely controlled Octane Requirement Increase (ORI) experiment. A variety of measures were employed to block out other variables. The two test oils were separately evaluated in two similar 1975 cars operating with commercial unleaded gasoline. A detailed analysis of the deposits resulting from 24,000 km (15,000 miles) of dynamometer operation supplemented the conventional octane ratings. Conclusive differences were not found in terms of observed ORI or in the total volume of combustion chamber deposits. However, the olefin copolymer VII was directionally lower in ORI and seemed to have a qualitative advantage in engine deposit formation and location. Several of the experimental techniques used in the current work appear to have potential for future study.

750939. The Application of Thermogravimetry to the Evaluation of Automotive Plastics. Stephen J. Swarin, Research Lab., General Motors Corp.

Because of the increasing use of rubber formulations and plastics by the automotive industry, analytical methods are continually being sought for quality control and receiving inspection. The application of the thermal analysis technique, known as thermogravimetry, to the problems of fast quality control analysis is discussed. Specific examples in the areas of relative thermal stability, analysis of additives, and compositional analysis of formulations are presented.

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750940. The Application of NMR Spectroscopy to the Analysis of Automotive Plastics. John E. Over, Mobay Chemical Corp.

The application of Proton and Carbon-13 Nuclear Magnetic Resonance Spectroscopy to the analysis of selected automotive plastics is discussed. Six nmr spectra are presented and the chemical shift values assigned to structural features for each polymer. The utility of nmr analysis for the characterization of organic polymers is illustrated by the application to the identification of polycarbonate thermoplastic and a polyurethane elastomer and to the determination of stereochemical configuration of poly(methyl methacrylate).

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750941. Scanning Electron Microscopy in the Rubber Industry. Ronald W. Smith, B. F. Goodrich Research & Development Center.

The scanning electron microscope is being applied in the rubber industry in two ways. First, as an extension of classical microscopy, the scanning microscope can provide a wealth of easily interpretable information about very complicated structures in a fast and precise manner. Second, by using this microscope as a micro x-ray

analyzer, the investigator can gain new and important information regarding the chemical composition at a microscopic level that had previously been unattainable.

These benefits apply to all phases of industrial technology, starting with investigations of raw materials and continuing on through product fabrication, product analysis, and product performance.

750942. Molecular Weight Distribution Ultimate Tensile Strength PVC Homopolymers. William A. Dark, Waters Associates.

Ultimate tensile properties are examples of a physical property which is relatable to the molecular weight of a polymer. Dilute solution viscosities of vinyl chloride homopolymers have classically been used to obtain an average molecular weight - tensile relationship. However, dilute solution viscosity measurements of todays' dispersion resins may not be a true indication of the PVC tensile strength.

Molecular weight distribution, from high speed GPC, has shown a direct correlation with PVC homopolymer ultimate tensile strength.

In addition, this technique will provide for rapid separation and quantitation of plasticizers and other additives in compounded PVC resins.

750943. Allis-Chalmers Flexible Manufacturing System. Kenneth E. Gross and Vincent N. Stromei, Allis Chalmers Corp.

This paper discusses a Flexible Manufacturing System, which has implemented design changes through simple program modifications. The system seems best suited for the manufacture of complex parts in intermediate quantities, showing poor returns on very simple parts or high production parts.

750944. Group Technology Concepts and Computer Aided Process Planning. Richard R. Wandmacher, Manufacturing Development, Technical Center, General Motors Corp.

The acronym CAD/CAM is familiar to people using Computer Aids for Design and Manufacturing. This paper will present CAPE, Computer Aided Process Engineering, a system that has its impact between Design and Manufacturing. Group Technology is a related activity which is useful in the development of a CAPE system.

Group Technology is a manufacturing concept of grouping items, in order to take advantage of their similarity. While neither the CAPE concept nor the Group Technology concept is new, an increasing need for expanding the application of the computer in the Manufacturing Engineering function has made these topics more frequent items of discussion and action. This paper will make an assessment of the need and applicability of the computer in manufacturing engineering, where this application stands now, and an insight into the development of needed software by an organization known as CAM-I

Computer Aided Process Engineering is a necessary part of the successful implementation of CAD/CAM systems. Very often it is an outgrowth of the implementation of a CAD system. When it is missing, the recognition that it is missing may help to explain why some CAD/CAM systems have not performed up to expectations. CAPE is a logical and necessary link between them. The output of a CAD system is the engineering design. The input to a CAM system is a plan to be executed by manufacturing. CAPE will take the design and turn it into a plan.

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750945. Computer Monitored Programmable Controller Systems. William S. Jack, Interautomation, Inc.

The application of mini computers in conjunction with programmable controllers provides the manufacturing manager with new control capabilities not available previously. These systems have the ability to monitor in real-time the actual operation of machine tools, conveyors, and processes and to report out-of-tolerance conditions as they occur.

750947. Paint Considerations of Coating Flexible Substrates. Donald Hart and Philip Boggs, Automotive Finishes Div., PPG Industries, Inc.

The effect of flexible automotive exterior substrates on paint procedures, flexibility, and durability.

750948. Developments in Automotive Applications of Hot Stamp Foil. Victor H. Rampelberg, Thermark Div., Avery Products Corp.

Hot stamp foil is being used to provide a color, a woodgrain or a metallic effect on hard surfaces, both exterior and interior. Quality and economy are achieved in areas ranging from a fraction of a square inch to 4,500 square inches. The technology now includes a system of applying a bright chrome foil to the soft polyurethane front and back ends of automobiles. Other developments include foil application to .015″ to .030″ ABS sheets, a new foil for thermoformable material, and the in-mold application of foil.

750950. Cold Forming Response of IN861. M. J. Koczak, R. Smith and H. Chung, Dept. of Materials Engineering, Drexel University.

Powder metallurgy cold forming processes provide several advantages: economy of material, minimal machining, close tolerances, high density and lower production costs. IN-861 is an air hardenable ferrous alloy of 2% Ni, 1% Mo, 0.7% Mn plus carbon produced from mixed elemental powders. Specimens were alloyed at three carbon levels and sintered at several temperatures in order to relate ductility and workability to alloy composition and preform sintering temperature. Results indicate that increasing carbon content and sintering temperature required increasing preform forming stresses. Also, duc-

tility of the preform increased with increasing sintering temperature and decreasing carbon content. Further additions of manganese raise the forming stresses, however a marked reduction in ductility is noted. Additions of molybdenum appear to have little effect upon strength, but decrease the ductility. The results indicate the optimum processing conditions, for example, composition and presintering temperature for workability and ductility of the IN-861 mixed elemental alloy system.

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750951. AISI 4000 Transverse and Longitudinal Impact Properties as a Function of Sintering Temperature and Deformation. Fran Hanejko, Hoeganaes Corp.

Increasing the sintering temperature, lowering the oxygen content, improved the longitudinal and transverse impact properties of powder formed AISI 4027. Flow improved the longitudinal impact properties to a maximum of 53 ft-lb but had no effect on the transverse properties. The anisotropy of powder formed preforms was a function of oxygen content and deformation strain. Comparing the powder-formed AISI 4027 to wrought AISI 8620, the powder formed preforms were more isotropic.

750952. Plastic Impregnation of P/M Steels. Carl J. Landgraf, Powder Metallurgy Div., A. O. Smith-Inland Inc.

The use of parts produced from metal powders is rapidly increasing. Advances within the last fifteen years in powder production, fabrication techniques, and processing equipment, have permitted fabricators to produce parts for a wide variety of applications.

Although some parts are used in the pressed and sintered condition, many are subjected to subsequent operations to improve the properties. Plastic impregnation is performed to produce a sealed part. This paper contains information about the characteristics of common P/M steels after plastic impregnation. With this knowledge, fabricators and users can utilize conventional P/M production for parts requiring a minimum of interconnected porosity. These parts are pressure-tight, can be electroplated readily, and machined easily.

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750953. Automotive Uses of Cemented Titanium Carbide. Herbert S. Kalish, Adamas Carbide Corp.

Cemented titanium carbide has been available for about 35 years, but it is only in the past 10 years that it has been used widely as a cutting tool. Its use in cutting tool applications has been widespread in automotive machining and there are also specialized applications where the material is being used as a wear part in connection with the automotive industry. This paper shows the application areas where cemented titanium carbide is most likely to be successful and outline its competitive place in contrast to the steel cutting cemented tungsten carbide grades, TiC coated grades, and ceramics. The importance of the use of cemented titanium carbide in the automotive industry, where machining speeds are increasing and productivity is becoming more and more important, is outlined. Laboratory test data comparing cemented titanium carbide grades to other cutting tool materials and field test applications will be shown.

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750954. Car Design For Economy and Emissions. Craig Marks and George Niepoth, Engineering Staff, General Motors Corporation.

Car design factors which affect fuel economy include body size and shape, vehicle weight, engine size and power train design. Computer simulation results are presented to illustrate some of the basic interactions which occur among these parameters. Exhaust emission standards and other practical constraints limit the quantitative usefulness of such parameter variation studies. The fundamental relationships between engine efficiency and exhaust emissions are reviewed. It is concluded that emission constraints are important and can limit the effectiveness of some design changes to improve fuel economy. With present technology, it can be shown that stringent exhaust emission standards will reduce fuel economy more than it can be improved by car design changes which do not seriously degrade many customer perceived values such as useful capacity, driveability and acceleration capability.

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750955. Road and Dynamometer Tire Power Dissipation. W. B. Crum, Ford Motor Co.

Torque-to-force and angular-to-translational velocity relationships for a driving tire are demonstrated to be associated with a radius significantly greater than and apparently independent of loaded height. Analyses and experiments which defined the above indicate the "rolling resistance moment" to be functionally dependent on loaded deflection of the driving tire and not directly related to power consumption.

Power dissipation through driving tire slip is derived and supported by experiments. Prior research, real road, single roll dynamometer, and twin roll dynamometer measurements are re-interpreted with the above corrections.

750956. Gasoline Engine Economy—A European Viewpoint. R. J. Forrester, D. Williams and K. J. Williams, Associated Octel Co., Ltd. (United Kingdom).

This paper gives background data on gasoline utilisation and the present status of fuel consumption procedures in Europe. The relationships between octane number requirement, compression ratio, and fuel consumption from current British cars of 1.0 to 4.0-litre capacity have been analysed. Published data are compared with results from dynamometer tests of engines and vehicles over a range of compression ratios.

Various vehicle operating cycles have been used to

show the consistently adverse effect on fuel consumption of lowering compression ratio, regardless of operating conditions. Gear ratio effects were also examined, and consumption trends were found to be dependent on the operating cycle.

An amalgamation of all results gives an economy relationship for European cars similar to that shown for American automobiles - 1.4% more fuel used per unit drop in octane number.

750957. Passenger Car Fuel Economy Trends Through 1976. T. C. Austin, R. B. Michael and G. R. Service, U.S. Environmental Protection Agency.

The fuel economy data compiled by the U.S. Environmental Protection Agency (EPA) have been analyzed to determine the trends in passenger car fuel economy beginning with model year 1957. This paper adds the 1976 model year data to the historical trend and concentrates on comparisons between the 1976 and 1975 models.

Calculation procedures which allow the changes in fuel economy to be determined separately for system optimization, new engine/vehicle combinations, and model mix shifts have been employed in the analysis which compares 1976 models with 1975 models. A wide range of percentage changes was seen for the fifteen manufacturers who were certified in time to be included in the analysis performed for this paper.

The net change in fuel economy for the 1976 new car fleet has been estimated at +12.8% compared to the 1975 new car fleet. System optimization is responsible for 8.8% of the improvement and model mix shifts are projected to account for +3.1% of the change. The improvements made on the 1976 models are projected to result in 1976 cars being the most fuel efficient produced since 1957, the earliest model year for which a significant amount of consistent fuel economy data exists.

The 17.6 mpg city/highway combined fuel economy projected for the 1976 models is 27% better than the 13.9 mpg 1974 model results which served as the basis for the Presidents Voluntary fuel economy improvement program which requested a 40% gain by 1980.

Whether the trend toward improved fuel economy which has been seen with the 1975 and 1976 models will continue in the future primarily depends on the degree of interest in achieving higher fuel economy on the part of the government, automotive industry, and motoring public. Compromises in the areas of cost, styling and acceleration performance could allow substantial improvements on some models. The effect of more stringent emission standards will largely depend on the degree of sophistication used in the design of spark advance systems, fuel metering systems and emission control systems.

750958. Factors Affecting Automotive Fuel Economy. J. Dillard Murrell, U.S. Environmental Protection Agency.

The EPA certification data base is the most extensive available body of information relating engineering variables to fuel economy. The range and distributions of these variables are presented in a non-sales weighted context. A multiple regression analysis, performed with careful attention to selection of optimum non-linear forms for some of the variables, shows that the most significant determinant of fuel economy is the parameter CID × N/V. Vehicle weight is second.

A sensitivity study on the isolated fuel economy effects of CID, N/V and weight confirms the superiority of CID as an influencing factor, and opens avenues for improving the structure of the forms of these variables in future regression equations.

A method is devised for quantifying ignition timing over a driving cycle in terms of a single "labeling" value usable as an engineering variable. Although not illustrated, the method is applicable to carburetion in similar fashion.

Relative fuel economy comparisons drawn between Federal (49-States) and California certification cars from the 1974, 1975 and 1976 model years show that an apparent inverse relationship between fuel economy and the stringency of emission controls can be overcome with the concurrent passage of time and the evolutionary application of improved technology.

750959. Characterization of CPE Elastomers for Automotive Applications. Vernon R. Amar and Lawrence E. Sollberger, Dow Chemical U.S.A.

This paper will discuss chlorinated polyethylene elastomers and their practical use to the automotive industry. Comparative data is presented which characterizes both the oil and heat resistance of the polymers. In addition, it will be shown that these properties can be attained without the sacrifice of weatherability, including ozone resistance and low temperature performance.

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750960. Improved Nitrile Rubbers with Polymerization Bound Antioxidant Stabilization. James W. Horvath, Goodyear Tire & Rubber Co.

Butadiene-acrylonitrile copolymers have been the preferred general purpose oil and fuel resistant elastomers in automotive, aircraft and industrial product applications for over 30 years. The need for improved service performance to meet more severe and/or newly emerging service requirements has prompted a number of studies to improve the performance of these polymers. This work has led to the development of a family of new and unique polymerization bound antioxidant stabilized nitrile rubbers which have outstanding heat resistance characteristics. These new rubbers also retain their age resistance qualities after exposure to oils or fuels which can extract the protective antioxidants from conventional nitrile rubbers thereby contributing to early failure of parts in service.

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750961. The Long-Term Heat Resistance of Epichlorohydrin Hose and Tubing Compounds. J. T. Oetzel, B. F. Goodrich Chemical Co.

Due to rising under-the-hood temperatures and the trend in industry in general for longer life products, the long-term heat resistance of elastomeric materials is generating considerable interest. This paper reviews some of the compounding techniques necessary to develop the best long-term heat resistant epichlorohydrin compounds. The long-term (1000 hrs.) aging resistance of these materials will be compared to more conventional materials such as CR, NBR, CSM and EPDM compounds. Also blends such as Acrylate/Epichlorohydrin and Epichlorohydrin/Chlorobutyl will be reviewed as ways to obtain a balance of heat resistance and cost.

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750962. Ethylene Propylene Elastomer Technology for Improved High Temperature Serviceability. R. S. Auda and D. R. Hazelton, Elastomers Technology Div., Exxon Chemical Co.

The heat resistance of ethylene propylene co- and terpolymer vulcanizates has been studied over temperatures from 212°F (100°C) to 347°F (175°C) and exposure times up to and sometimes exceeding 1000 hours. Most established heat aging analyses rely on separate treatment of two parameters, retention of tensile strength or retention of elongation, to predict acceptable performance. This paper discusses a method with which to study aging behavior that combines these parameters into a single expression, the fractional strain energy at break, which describes an aged vulcanizate in terms of both its integrity (retained tensile) and its extensibility (retained elongation). Use of fractional strain energy at break is shown to be a reliable means of characterizing and projecting ethylene propylene aging behavior.

Compounding principles which affect ethylene propylene long term heat resistance are demonstrated in the paper. These include the importance of the proper vulcanization system, the effects of different fillers and plasticizers, the original quality level of the vulcanizate, and the selection of special additives to improve aging. Most of the data presented feature ethylene propylene terpolymers (EPDM), which offer a good balance between heat resistance and compounding versatility; however, for those EP uses which require maximum long term, high temperature resistance, it is shown that the best serviceability is achieved with ethylene propylene copolymers (EPM).

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750964. Driver-Vehicle Performance In Closed Loop Tests. Gordon G. Hayes, Rodger J. Koppa, J. Tom White and Monroe C. White, Texas Transportation Institute, Texas A&M University.

Closed-loop maneuvers were performed by a cross-section of typical drivers in four representative automobiles. The tests included both preplanned control tasks and "spontaneous" reactions to sudden obstacles or visual instructions. On the average, the drivers did not achieve the open-loop limit performance of the cars. Directional response parameters were the more significant indicators of differences in performance between vehicles.

750966. Cumulative Fatigue Damage Analysis of a Light Truck Frame. M. R. Mitchell, University of Illinois; and R. M. Wetzel, MTS Systems Corp.

A case study describes a fatigue damage analysis of a light truck frame. The objective of the analysis is to determine whether an existing frame design can safely accept a ten percent increase in load. The analysis, completed in less than a month, incorporates an experimental stress-strain analysis, proving ground test data and experimentally determined properties of the frame material. Three common methods of damage analysis and a relatively new procedure are compared and the advantages of the new method are demonstrated.

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750967. A Coating for the Preservation of Fracture Surfaces. Bruce E. Boardman, Deere & Co., R. Zipp, International Harvester Co.; and W. A. Goering, Ford Motor Co.

In order to perform a meaningful examination of a fracture surface in the scanning electron microscope it is necessary for the examined surface to be in a condition as close to the fractured condition as possible. Laboratory preservation techniques are not available to the engineer in the field so the fracture surfaces are best preserved by coating them with a material that can be easily removed later without damage to the fractures. In this paper, a preservative is described that is suitable for the protection of fracture surfaces both in the field and in the laboratory. The restrictions and limitations of the preservative are discussed and examples of fracture surfaces before coating and after coating and exposure to a humidity cabinet are shown.

750968. The Fatigue Life of Vehicle Frame Structures. Matolcsy Mátyás, Research Institute of Automobile Industry (Hungary).

The stresses arising in a vehicle structural part during the operation period could be divided into three essential components. The extreme values of these components and their distribution function may be derived. Using appropriate crack propagation functions one can define the momentary service strength of the structure and the damage-function. On the basis of the new fracture model presented, the life distribution can be interpreted unambiguously. By using certain assumptions, the deverage value and the scatter of the life can be derived. The new fracture model allows the several fracture types, like static, pure dynamic, pure fatigue, and general fractures to be treated on the same basis.

1975 SAE Transactions

750969. Problem Areas in Sampling and Analyzing VCM. Howard E. Williams, Davidson Rubber Co., McCord Corp.

New OSHA requirements regarding the use of VCM (vinyl chloride monomer) have been found to present specific problems with certain sampling methods and analytical procedures. This report will attempt to define some of these problem areas.

750972. Material Alternatives for Today's Emission Control System. D. E. Blandy, Jr., Bethlehem Steel Corp.

Two recently developed sheet products offer material cost savings opportunities of approximately $2.50 per typical car with catalytic conversion system.

Galvalume sheet steel, an aluminum-zinc alloy coated sheet, has been used successfully for grass shields replacing type 1 aluminum coated sheet at an approximate savings of 25¢/lb.

Chromized sheet, which has a diffused layer of ferritic stainless steel on both surfaces of a special low carbon sheet, is suggested as a substitute for 400 Series Stainless Steel at a material cost benefit of approximately 15¢/lb. Exhaust inlet tubes and convertor shells of Chromized have been successfully tested.

750974. Competition Motorcycle Noise Measurements —A Correlation Study. Robin T. Harrison, USDA Forest Service; and Roger Hagie, Kawasaki Motors Corp.

A noise measuring program during the running of flat-track races for 750-cc, four-stroke, twin-cylinder competition motorcycles showed that the noise measured under actual track conditions correlated fairly well with the American Motorcycle Association's (AMA) 4,000-rpm static test method of predicting noise. Equations are presented that, if substantiated, can be used to accurately forecast from the AMA static test results the noise levels that will be generated during such events. The motorcycles, equipped with mufflers, projected significantly fewer decibels into the local community than local officials had deemed objectionable. However, the racing cyclists and their pit crews experienced noise levels loud enough to cause permanent irreversible hearing damage.

751001. (SP-396) **Combustion Process Fundamentals and Combustion Chamber Design for Low Emissions.** H. K. Newhall, Mechanical Engineering Dept., University of Wisconsin.

This paper discusses basic combustion process modification as a means for emissions control. It has recently been shown that modified combustion systems can in principle lead to reduced emissions. Several of these systems, which fall into the broad category of stratified charge systems, will be discussed in this paper.

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751002. (SP-396) **Emission Formation Characteristics of the Diesel Combustion Process and Estimated Future Development Trends.** J. C. Hoelzer, J. I. Case Co.

A review of the fuel consumption per capita and population trends is presented which suggests that any significant relaxation in diesel emission goals is undesirable.

An analysis is then made of the chemical, thermodynamic and fluid dynamic factors which control the formation of nitric oxide, unburned hydrocarbon, carbon monoxide and exhaust smoke in diesel combustion. Based on this analysis it is hypothesized that a reduction in the quantity of fuel burned in diffusion flames and increased mixing rates of air and fuel vapor will significantly lower emission levels. It is suggested, therefore, that future trends in direct injection combustion development will need to incorporate increased fuel atomization and toroidal air motion to achieve the required favorable combustion conditions.

A comparison is made of commercially acceptable, state-of-the-art diesel engines developed to meet low emission levels to allow an estimate of the potential improvements from combustion development. The comparison suggests that intense mixing and good fuel atomization, characteristic of the prechamber process, are the keys to lower emissions and can yield up to 40% of reductions in HC + NO_2 levels for the direct injection diesel combustion process.

A forecast of future engine requirements is made and indicates that hybrid engines combining the diesel and Rankine cycles are feasible for heavy duty engine applications. The combination of the highly efficient diesel cycle and a reciprocating steam engine using diesel engine exhaust energy is a potentially efficient, low emission, socially acceptable prime mover.

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751003. (SP-396) **Reducing the Transmitted Vibrations from Single Cylinder Engines.** Alfred W. Siman, Homelite Div., Textron.

Simplified curves and equations are developed that can be used to predict the vibration level of a supporting structure from the action of the various vibration sources of a slider-crank mechanism.

Using a chain saw as an example, the vibration levels from each major vibration source are presented together with the vibration level with various isolation stiffnesses as presently used in practice.

The vibration levels are reviewed to determine the design parameters necessary to meet a 0.5 "g" specification, and a novel isolation concept is presented together with actual vibration spectrums.

751004. (SP-396) **Prechamber and Valve Gear Design for 3-Valve Stratified Charge Engines.** Michael C. Turkish, Eaton Corporation.

It is recognized that stratified charge combustion in a spark ignited internal combustion engine can produce

improved fuel economy. A historical summary of many significant patents and articles is given pertaining to the 3-valve form of this engine combustion principle. The present social need of reducing exhaust emissions, and the renewed goal of improving fuel economy, makes this engine form one practical approach to the "clean engine" being sought for vehicular use. It uses a rich prechamber charge to provide the proper stratification. The prechamber can vary considerably in size depending upon the goals sought and the engine application.

A basic requirement is that the fuel-air equivalence ratios of the charges in the two combustion chambers are within certain limited ranges to achieve proper optimization. The ratios should be 15% rich for the prechamber and 15 to 30% lean for the main chamber at the moment of ignition. The fuel-air equivalence ratios of the two carburetors must be properly selected to achieve these ratios within the combustion chambers. With the use of a computer analysis of engine breathing and carburetor air-flow the proper fuel-air equivalence ratios of the two carburetors can be conveniently established.

Typical valve gear and prechamber layouts relative to the auxiliary valve are illustrated for various types of engines. Controlled charge turbulence and good charge mixing are very important, in addition to developing the recommended fuel-air equivalence ratios, to achieve dependable ignition and combustion. Some air swirl within the main chamber is desirable for this reason. A thermal reactor for the exhaust gases is complementary to this engine structure as verified by laboratory tests.

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751005. Automotive Design and Materials Selection. James Boyd, Materials Associates, Inc.

Fantastic changes are taking place in our use of resources and in our life style. The industries that supply raw materials are being bombarded by demands. All are interrelated, and to fix one problem aggravates another. This paper discusses solutions to these problems, solutions which will require more material substitution for a given application. These solutions will require our technological society and government regulations to adjust to new systems to find an adequate resolution.

751006. Seat Belt Use Inducing System Effectiveness in Fleet Automobiles. Michael R. Appleby, Louis J. Bintz and John C. Wolfe, Automotive Engineering Dept., Automobile Club of Southern California.

Seat belt use inducing systems and seat belt use counting systems were installed in fleet vehicles of the Automobile Club of Southern California. The results were:

1. Mean group seat belt use for three use inducement systems were sequencing system 77%; ignition interlock system 86%; and speed limiting interlock system 81%.

2. There was no significant change of seat belt use for any of the three inducement systems according to time of exposure.

3. There was a significant difference between previous no system seat belt use (mean 24%) and no-system seat belt after exposure to the use inducing system (mean 49%).

4. The vehicle drivers were given a questionnaire at periodic intervals, the results of which indicated higher self-reported than actual seat belt use. Also specific confusion, inconvenience and discomfort factors were identified and rated.

The conclusions were:

1. Use inducing systems cause a significant increase in seat belt use of fleet vehicle drivers. This increase, while probably of a different magnitude, will occur in vehicles operated by the general public.

2. No one use inducing system tested was significantly superior in increasing seat belt use than another.

3. Temporary exposure to a use inducing system appears to cause a permanent increase in the non-induced seat belt use of exposed subjects.

4. Improvement of seat belt hardware and geometry related to the human factor engineering aspects may further improve seat belt use.

751009. The ISO Standard Guide for the Evaluation of Human Exposure to Whole-Body Vibration. H. E. von Gierke, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base.

This paper was prepared by invitation as discussion of SAE Paper 750166 by R. N. Janeway, "Human Vibration Tolerance Criteria and Application to Ride Evaluation," presented at SAE Automotive Engineering Congress, February 1975. It discusses the present ISO Guide for the Evaluation of Human Exposure to Whole-Body Vibration, which is based on all relevant information presently available and which reflects the best judgment of all international experts and all disciplines involved.

751010. Inertia Brake Dynamometer Testing Techniques For FMVSS 121. Donald E. Steis, Research Center, Abex Corp.

This is a discussion of the need for standardization in inertia brake dynamometer techniques and the basic principles for setting up a "S" cam air brake for evaluation under laboratory conditions. Specific brake conditions show the need for standardization of brake set-up for obtaining the optimum output from a brake and friction material combination.

751012. The Effect of "S" Cam Brake Component Variation on Performance. Paul A. Myers, R/M Friction Materials Co.

The re-evaluation of the brake blocks part of the "S" cam foundation air brake system established new understanding of component variation and interactions on performance. Each of the significant components must be understood and controlled to obtain desired performance consistency. The simple "S" cam brake is actually a complex system of variables requiring cautious evaluation.

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751013. Evaluation of Gray Iron Brake Discs for Trucks by Thermal Modeling. H. W. Schwartz, L. L. Hartter, S. K. Rhee and J. E. Byers, Bendix Corp.

Lower temperatures at the sliding interface of a disc brake will reduce thermal wear and fade tendencies of friction materials. One method for achieving these lower temperatures is to improve the thermal design of gray cast iron discs.

The purpose of this investigation was to study design improvements of brake discs for trucks. To accomplish this objective, an analytical thermal model was developed. The model employed the lumped parameter approach, in which the disc was subdivided into a number of small volumes. The model specifically simulated disc temperature response during 80.5 km/h (50 mph) fade tests performed on a dynamometer. The thermal model was correlated with test data to verify and improve its accuracy, and then utilized to evaluate effects of geometry changes.

Results showed that mass concentration in the disc faces yields lower temperatures at the friction interface through 10 successive snubs. Even after a very large number of snubs, temperature cycling would be less extreme with thicker faces.

The study has demonstrated that thermal modeling is a valid and potentially valuable tool in the design optimization of brake discs. Indeed, the analytical approach, combining both thermal and stress analyses, along with prototype testing, may prove the most effective method for future design development of disc brakes.

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751014. Cooling Analysis of Disc Brake Rotors. Rudolf Limpert, Mechanical Engineering Dept., University of Utah.

This paper presents equations for determining the convective heat transfer coefficients of solid and ventilated disc brakes. Analysis of data indicates that the cooling capacity of a ventilated rotor is sharply reduced at lower speeds, and most cooling is provided by the increased surface area. A general relationship derived from road test data is presented that yields the heat transfer coefficient for both disc and drum brakes of commercial vehicles.

751017. A New Concept in Cab-Over-Engine Truck Design. Wayne K. Simons, Kenworth Truck Co.

IN 1973, AN EXPERIMENTAL C.O.E. class eight highway vehicle was designed and built by Kenworth Truck Company to evaluate market impact generated by a unique looking vehicle. Various design aspects as related to driver comfort and associated component development are presented.

To provide separate sleeping accommodations for two people, total cab height from current production models was increased by 22 inches. This increase was also used to develop a roof contour with esthetic valve and moderate air flow characteristics to the extent possible. In addition, a brief summary of actual road testing is presented.

751018. A New Concept for Heavy Duty Highway Tractors. John W. Zimmerman, Jr. and Clifford E. Peterson, International Harvester Co.

Prior to World War II, most heavy duty highway trucks and tractors were built as Conventionals, that is, with the cab mounted behind the engine. In the late 1940s cab-over-engine types gained acceptance and in the 1950s the tilt cab COE was developed in its present form including sleeper cabs.

The new concept is to combine the best features of conventionals and tilt cab COEs to develop a superior non-sleeper tractor that makes no compromises for sleeper cab types.

751019. Modern European Highway Truck Design — The Bedford TM. A. J. McKay, General Motors Overseas Operations Div., General Motors Corp.

The design and operation of highway trucks in Europe is subject to legislation which is more detailed and restrictive than in the United States. The operating environment and consequently the market preferences frequently differ from those in North America.

This paper discusses the important European legislation and marketing factors affecting truck design and describes the major features of a new range of heavy duty trucks designed primarily for operation in Europe. Some of the differences between European and North American highway trucks are also reviewed.

751041. Digital FWB Flight Control and Related Displays. David S. Hooker and George J. Vetsch, McDonnell Aircraft Co.

An exploratory definition study has been conducted for an Advanced Fighter Digital Flight Control System. The principal objective was to derive and evaluate custom multimode control laws, related displays, and multichannel digital fly-by-wire implementation schemes for advanced Air Force and Navy fighters.

Study results show that a triplex flight control system provides the lowest weight, the best maintainability, and the lowest cost of the candidate configurations considered. Results also indicate that mission-oriented flight control laws integrated with compatible displays and controllers can provide enhanced mission effectiveness and reduced pilot workload.

It is recommended that the concepts analyzed and simulated during this definition study be implemented and evaluated by flight testing.

751044. Design Freedom Offered by Fly-by-Wire. Clifford F. Newberry, Wichita Div., Boeing Co.

Fly-By-Wire offers the designer flexibility in mechanizing the manual flight control system and makes possible potential CCV performance benefits because more complex functions can be implemented. The full potential of

FBW and CCV can only be achieved by incorporating these concepts in the initial design phase of a new airplane. Greater benefits are obtained in several areas when applying FBW and CCV simultaneously.

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751046. Fly-By-Wire Flight Control System Design Considerations for Fighter Aircraft. Elmo C. Livingston, Fort Worth Div., General Dynamics.

The application of fly-by-wire flight control systems in fighter aircraft influences the basic design of the aircraft and requires special attention to certain design characteristics of the control system. The use of control-configured vehicle concepts for performance benefits makes fly-by-wire a logical choice. Redundancy management, protection against power loss, lightning protection and controller selection are prime design factors to be considered. Flight testing of the YF-16 aircraft has demonstrated excellent performance and operating characteristics of its fly-by-wire flight control system.

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751047. Progress Report on the Gatorizing™ Forging Process. R. L. Athey and J. B. Moore, Pratt & Whitney Aircraft.

The GATORIZING Forging Process (U.S. Patent No. 3,519,503) is being successfully applied to the production of large IN100 alloy compressor and turbine engine disks for an advanced production jet engine. The process has enabled these disks to be made with a reduction of billet input weight of approximately 50% compared to the input weight that would be required to forge identical configurations from weaker superalloys. As a result of a large background of experience with the GATORIZING process and improvements in disk inspection procedures, it is now feasible to reduce the billet input weight for the same forgings by another 50%, for a net reduction of 75%. This reduction, of course, represents a very significant cost reduction in terms of billet input cost and part machining cost.

The applicability of the GATORIZING forging process to the forging of low cost rotor components of the advanced superalloys for industrial gas turbine engines is also discussed.

751048. Experience with Integrally-Cast Compressor and Turbine Components for a Small, Low-Cost, Expendable-Type Turbojet Engine. Robert P. Dengler, Lewis Research Center, NASA.

A discussion regarding experiences with integrally-cast compressor and turbine components during fabrication and testing of four engine assemblies of a small (29 cm (11 1/2 in.) maximum diameter) experimental turbojet engine design for an expendable application is presented. Various operations such as metal removal, welding, and re-shaping of these components were performed in preparation of full-scale engine tests. Engines with these components have been operated for a total of 157 hours at engine speeds as high as 38,000 rpm and at turbine inlet temperatures as high as 1256 K (1800°F).

751049. Rene 125, Development and Application. Peter Aldred, Aircraft Engine Group, General Electric Co.

This paper describes the development of René 125, a nickel base superalloy designed for turbine application in advanced gas turbine engines. The derivation of its composition is described. The strength of René 125 is shown to have 60°F temperature advantage over René 80, the current General Electric production turbine blade alloy. The rupture strength and creep rate of René 125 are dependent on heat treatment. When René 125 is coated with an aluminide (CODEP) there is a beneficial interaction between alloy and coating chemistries resulting in a significant improvement in the oxidation resistance of the coating. Complex cored blades have been successfully cast from René 125 and blades are currently being evaluated in engine tests.

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751050. Trends in High Temperature Materials Technology for Advanced Aircraft Turbine Engines. Charles P. Blankenship, Lewis Research Center, NASA.

Approaches to the development of improved high temperature engine materials are reviewed. Emphasis is placed on emerging materials technologies and their potential benefits to aircraft gas turbine engines. Advances in materials processing technology are considered also, with emphasis on areas of potential cost reduction. This review also examines a changing approach to the selection of turbine engine materials technologies for future development. This changing approach places greater emphasis on the overall economic benefits to the aircraft system rather than improved engine performance.

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751051. Impact of Active Controls on Future Transport Design, Performance, and Operation. R. L. Schoenman and H. A. Shomber, Boeing Commercial Airplane Co.

Active Control Technology concepts hold considerable promise of improved efficiency for commercial transports. The application of these control concepts to current transport airplanes has typically been non-design impacting - that is, the design proceeded in a conventional manner. Realization of the potential of ACT will require a departure from this design procedure, requiring new approaches to the airplane design process.

The paper briefly describes ACT and reviews existing transport airplane configurations to point out that ACT is not particularly new or novel. Following an examination of where the payoffs are for a new airplane - considering the sensitivity to design speed, range, configuration, and size - the risks associated with ACT implementation are reviewed.

The impact of ACT on the transport airplane design cycle is discussed to illustrate the challenges that lie ahead. An initial commercial application strategy is then proposed for incorporation of each of the specific ACT concepts.

The user of a commercial transport views ACT from a different point of view. This point of view and the impact on certification are briefly discussed, recognizing some of today's difficulties and pointing out the probable benefits available through new technology.

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751052. ACT System Design for Reliability, Maintainability and Redundancy Management. J. E. Emfinger, Flight Systems, Div., Sperry Rand Corp.

The specifications of design requirements for Active Control Technology (ACT) flight control systems are addressed based on current state-of-the-art trends with emphasis placed on the impact of specific requirements on system mechanization. Of particular interest is the sensitivity of the ACT system design to redundancy managment, reliability and maintainability requirements, and to the related subsystem interface concepts. Experience on both military and commercial aircraft programs is cited to provide insight to establishment of practical design requirements for ACT systems.

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751056. Future SST Engines with particular reference to Olympus 593 Evolution and Concorde Experience. P. H. Calder and P. C. Gupta, Rolls-Royce (1971) Limited Bristol Engine Division (United Kingdom).

The current achievements of Concorde and its powerplant are summarised, and the route by which technology may be evolved for making further SST performance and environmental advances appropriate to a second generation aircraft is indicated. Experimental data on take-off noise is discussed. Future improvements in turbine cooling technology applied to a turbofan of around 1.7 bypass ratio, together with possible future improvements in aircraft L/D and structure weight, should permit the development of an SST with substantial increases in payload percentage and range relative to Concorde while meeting current FAR Part 36 noise limits without a suppression system. The engine could be derived from the current Olympus 593 Mk 610.

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751058. Track-Train Dynamics. Peter W. Abbott and George Morosow, Martin-Marietta Corp.; and Jack Macpherson, Marshall Space Flight Center, NASA.

The purpose of this paper is to outline one of the serious dynamic problems involving railroad cars and to propose an orderly approach to the definition of a dynamic model through analysis and testing that can be used to investigate various fixes. The problem in question is the hunting phenomenon involving lateral instability of the car suspension (trucks). This phenomenon has been recognized as a major contributing factor in a significant number of derailments causing millions of dollars in losses. This paper expounds on the mechanics and characteristics of hunting. The planned solution is outlined as a building block approach directed at formulating a test verified dynamic model of an open hopper freight car-truck assembly. Results obtained to date are presented together with conclusions related to the program.

751059. Dynamic Analysis of Rail-Vehicle Systems Using Dynalist II. T. K. Hasselman and A. J. Bronowicki, J. H. Wiggins Co.

The purpose of this paper is to introduce the DYNALIST (Dynamics of Articulated Linear Systems) computer program and demonstrate its application to rail-vehicle systems. The program is available through the U. S. Department of Transportation, Transportation Systems Center, and offers general modeling and computational tools for linear analysis in the frequency domain based on modal superposition. The paper describes the lateral dynamic analysis of a passenger-type vehicle including calculations for sinusoidal, periodic and stationary random rail irregularities. A transient response capability is also demonstrated. Approximate results based on modal truncation are compared to exact solutions.

751060. High-Speed Dynamic Performance of the Linear Induction Motor Research Vehicle. C. C. Chi and G. O. D'Sena, AiResearch Manufacturing Co. of California, div., Garnett Corp.

The linear induction motor research vehicle (LIMRV) recently set a world speed record of 255.7 mph for steel-wheel-on-steel-rail vehicles during a series of test runs conducted on the 6.2 mile-long experimental track at the Transportation Test Center, Pueblo, Colorado. This paper presents performance data on LIMRV dynamics associated with acceleration, steady-state operation, and braking, as recorded during these tests. Actual test results are compared with analytical predictions. Difficulties encountered are discussed and their solutions described.

751061. Electronic Fuel Controls for Missile and RPV Gas Turbines. G. D. Cropper, Chandler Evans Control Systems Div., Colt Industries.

Current gas turbine fuel controls for unmanned applications usually employ electronic computation controlling a basic fuel handling package. Several possible fuel handling systems are discussed, and examples of a simple target drone control and more complex cruise missile control are described in some detail. Finally, some comments are made on likely future trends in electronic computer design.

751062. Failure Survival Aspects of a Digital Fuel Control

System. J. F. Bussell, Marconi-Elliott Avionic Systems Ltd.

The paper concerns the design of an engine mounted, electronic, digital fuel control system for a twin coupled, helicopter engine configuration. The system is described from the point of view of the failure survival requirements, and the paper highlights the contribution of the digital system to the implementation of these requirements, and the environmental design techniques adopted to achieve maximum reliability.

751063. A Design Study of the Application of a Simplified Aircraft Fuel Control Method to Automotive Gas Turbines. Harold Gold, Lewis Research Center, NASA.

The results of a design study of the application of a simplified aircraft fuel control method to automotive gas turbines is presented. Although the requirements for control of automotive gas turbines impose a degree of complexity exceeding that of fixed geometry aircraft engines, the hydromechanical computing circuit employed in the earlier application is found to be applicable to the automotive requirements. Methods for compensation and/or adjustment for wide range fuel density and inlet temperature variations and for obtaining turbine vane actuation, acceleration optimization, and turbine braking are presented.

751064. Evolution of an Electronic Fuel Control for Industrial Gas Turbines. Jan Ederveen, Woodward Governor Co.

The purpose of this paper is to describe the development of the 43027 electronic fuel control system, which is designed to service a wide variety of industrial gas turbine users. It also discusses applications of the fuel system.

751066. Modal Test: Measurement and Analysis Requirements. Ben K. Wada, Jet Propulsion Laboratory.

Analysis of modal test data prior to dismantlement of the test setup is required to assure high quality data. Often erroneous or incomplete data, which are detected after the test, do seriously compromise the value of the test itself. With the advent of minicomputers for modal testing to reduce the test duration, a larger burden exists on rapid data analysis to support the test. The experiences at the Jet Propulsion Laboratory in data analysis and its presentation are described. Data analysis results from the Viking Orbiter Program are used to illustrate the analysis and its presentation.

751067. Modal Survey Techniques and Theory. E. Sloane and Bruce McKeever, Time/Data Corp.

The evolution of multiple shaker induction of pure modes has nonetheless retained a key assumption and consequent test procedure a quarter of a century old — mode vectors are real, that is, in phase except for polarity and therefore an in phase force vector should be applied at a single frequency along the $j\omega$ axis. The validity of the assumption and procedure is limited to undamped or proportionally damped structures. Modern, complex and inhomogeneous hardware seems less likely to satisfy the limiting assumption. The complex modes of nonproportionally damped structures can be induced with two improvements on existing procedure made possible by modern electronics and digital computers — apply a force vector controlling AMPLITUDE and PHASE and allow COMPLEX FREQUENCY EXCITATION anywhere in the s plane.

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751068. Modal Survey Activity Via Frequency Response Functions. Albert Klosterman and Raymond Zimmerman, Structural Dynamics Research Corp.

In recent years, the development of digital signal processing hardware and software has progressed to the point where frequency response functions can be measured in a fraction of the time required by previous measurement techniques. This has caused a renewed interest in convenient and reliable software for effective modal survey work via frequency response functions to manipulate, store, retrieve and display frequency response functions, perform on-line modal parameter estimation, display resulting mode shapes and check the accuracy of the results. This paper reviews the relationship between frequency response functions and modal parameters and presents the software architecture used by the authors for effective use of frequency response functions in a modal survey activity.

751069. Space Vehicle Experimental Modal Definition Using Transfer Function Techniques. C. D. Knauer, Jr., A. J. Peterson and W. B. Rendahl, Hughes Aircraft Co.

In early 1975, a Hughes-built communications satellite was subjected to a ground vibration survey test to determine resonant frequencies, modes, and damping characteristics. Two different techniques were independently utilized to define the space vehicle vibration modal parameters. One consisted of the classical technique where multiple shakers were used to tune in a single resonance to define its frequency and normal mode shape. The second approach utilized recent technology and a data processing technique which provides for more complete data acquisition in a shorter actual on-the-floor test time. The latter method uses a single point random excitation to provide all the data required, which then undergoes a considerable amount of data processing. Transfer functions are computed for each accelerometer location from which the modal properties are assembled. The subject paper describes the two test techniques, data reduction, processing required, and a comparison of results.

751070. Applying Resilient Foil Air Bearings to Turbomachinery — Techniques and Challenges. S.

Gray, Mechanical Technology, Inc.

A review is presented of the features which make the resilient foil air bearing attractive in high temperature and high-speed turbomachinery. Turbomachinery requirements are considered with emphasis on automotive gas turbines in which sometimes both air and oil lubricated rotor bearings are used.

Techniques used in designing and matching foil bearings to the gas turbine and economically developing them under simulated operating conditions are discussed together with some developmental experiences.

The construction of foil bearings, their materials and coatings, manufacture and accuracy is reviewed.

A look is taken at the future challenges of anticipated higher cycle temperatures and speeds where 1400°F bearing soakback temperatures may exist and the all foil bearing rotor system will be required. The possibility of ceramic foil bearings is considered and an example of some new technology work is used to illustrate the continuing development work which will be required.

751071. Development of Compliant-Mounted Gas Bearings for a High-Speed Turbomachine. W. Shapiro, R. Colsher and F. Kramberger, Franklin Institute Research Laboratories.

This paper describes the analysis, design and development of compliant-mounted gas lubricated journal and thrust bearings for supporting a 12 lb, 93,500 rpm, turboalternator rotor. Component testing of the bearings demonstrate excellent load capacity and start-stop capability. It was found that lift off could be achieved at low speed (400 rpm) and under high unit loads (7 psi). Simulator tests were accomplished to speeds of 60,000 rpm. Full speed testing was aborted by a journal bearing failure, due to a blockage of cooling-air flow.

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751072. Evaluation of a Gas-Lubricated Foil Bearing for Control of Gas Turbine Engine Rotor Critical Speeds. R. H. Badgley, Mechanical Technology Inc.; and J. Reddecliff, Pratt & Whitney Aircraft Div., United Aircraft Corp.

The effectiveness of gas-lubricated foil bearings for use in reducing small gas turbine rotor vibration levels has been evaluated through application of the Hydresil™ foil bearing to a power turbine shaft simulator, operating in flexibly-mounted ball bearings without support damping. A series of tests showed the three-pad Hydresil bearing to be superior to the 360-degree and two-pad configurations for the journal size and speeds tested. In-place multiplane-multispeed rotor balancing was used to establish a "baseline" rotor which had the first (bending) shaft-bearing system critical speed and a pedestal resonance suppressed, and a distinct vibration peak at the second (bending) critical speed. The test Hydresil proved to be capable of increasing the second critical speed by over 50%, as evidenced by a shift of the resonance peak to a speed above the normal operating speed range of the power turbine shaft.

751077. Fairchild Republic Advanced Fighter Technology Integrator (AFTI)—Phase 1 Program Review. Gordon Rosenthal, Fairchild Republic Co.

A study was made of desirable advanced fighter technologies for integration into a demonstrator aircraft which would be used to evaluate combat effectiveness. The demonstrator aircraft configuration development is traced, and its physical and performance characteristics are summarized. The technologies incorporated are described and their performance characteristics and benefits are discussed and substantiated by applicable wind tunnel or manned simulation results. Key technologies include: advanced aerodynamic configuration, advanced structural concepts; integrated maneuvering nozzle, variable incidence outer wing panel, variable camber, chin fin, multi-mode digital fly-by-wire control system, integrated fire control system, and high acceleration crew station.

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751079. Vectored Lift Advanced Fighter Technology Integrator. T. A. Gibbons and H. H. Ostroff, McDonnell Aircraft Co.

The Advanced Fighter Technology Integration (AFTI) program was conceived to provide the mechanism for orderly transfer of Air Force technology programs into operational systems. This paper presents the results of the McDonnell Aircraft Phase I AFTI study, which involved identification of high-payoff, mature technologies, the integration of these technologies into effective operational configurations, the design of manned demonstrator aircraft, and the validation of a selected concept through windtunnel tests and manned simulation.

The Phase I study verified the program premise that fighter/attack aircraft with greatly improved effectiveness are achievable with recently emerged technologies, if these technologies are integrated during the conceptual phase so that they literally shape the vehicle.

The Vectored Lift Fighter (VLF) is such a concept, employing new flight and control modes. In the air-to-ground role, this advanced technology fighter/attack aircraft, when compared in sophisticated manned simulation with a baseline representative of the best current technology, killed one-and-a-half times as many targets while sustaining only one-fourth as many losses. In air-to-air engagements, it killed twice as many targets while sustaining only one-sixth as many losses.

Perhaps the most significant finding was that the effectiveness of fighter/attack aircraft employing these new flight and control modes cannot be properly assessed by traditional performance parameters.

751081. The Application of New Technology to Military Aircraft Structure. George P. Haviland, Barbara J. Hanyecz and C. H. Hamilton, Rockwell International Corp.

The paper presents some of the problems encountered when advanced technology hardware and/or software are made a part of an ongoing system such as the B-1 bomber. The introduction of diffusion bonded Titanium, superplastically formed parts and the use of boron reinforced longerons are three examples of new technological applications of hardware. The requirement to conduct a fracture mechanics control program, the new computer program to determine the combination of the fatigue effects and fracture behavior and a new flutter optimization methodology are three other examples of new applications of software to a military aircraft. The paper treats each example to show why it was adopted, the pressing need to make it work in the real world outside the laboratory and some of the problems of using the new technology which were not anticipated.

751083. Technology Requirements for Advanced Energy Conservative Turbofans. Robert Neitzel, General Electric Co.; and James Dugan, Lewis Research Center, NASA.

The technology requirements for new subsonic transport engines which might go into service in the mid 80's are discussed with the emphasis placed upon improving energy consumption and aircraft economics. A typical advanced turbofan engine is described. Effects of variations in major cycle parameters on fuel usage and direct operating cost (DOC) of advanced aircraft designed for 0.8 Mach no. are shown. The impact of specific engine design and technology features including component aerodynamic and mechanical improvements, high temperature materials and cooling, composites, and advanced nacelle designs are also shown and related to the technology advances required.

751085. General Characteristics of Fuel Conservative Prop-Fan Propulsion System. S. M. Hudson, Detroit Diesel Allison Div., General Motors Corp.; and B. S. Gatzen, Hamilton Standard Div., United Technologies Corp.

The concerns for limited availability of petroleum based fuels and the upward cost spiral of oil have resulted in great interest in fuel consumption in the aviation sector of transportation. NASA has conducted studies to identify and accelerate the development of promising advanced technologies appropriate for achieving fuel conservative aircraft for the next generation of commercial transports. Several advanced technologies in the airframe and propulsion disciplines have been identified by NASA, with the turboprop being one of these. Two decades of turboprop technology advances are discussed along with their application to a Prop-Fan propulsion system for modern high-speed commercial aircraft. The Prop-Fan propulsion system features a small diameter, multibladed propulsor geared to an advanced gas turbine engine. The Prop-Fan's substantial improvement in thrust specific fuel consumption over the turbofan for operations up to Mach 0.8 as well as its acoustic character in the far and near field are reviewed. A more in-depth look at nacelle arrangements, component technologies, system weights, and reliability and maintenance is included.

751086. Variable Cycle Engines for Advanced Supersonic Transports. Robert A. Howlett and Hilary Kozlowski, Pratt & Whitney Aircraft Div., United Technologies Corp.

Variable Cycle Engines being studied for advanced commercial supersonic transports show potential for significant environmental and economic improvements relative to 1st generation SST engines. The two most promising concepts are: a Variable Stream Control Engine and a Variable Cycle Engine with a rear flow-control valve. Each concept utilizes variable components and separate burners to provide independent temperature and velocity control for two coannular flow streams. Unique fuel control techniques are combined with cycle characteristics that provide low fuel consumption, similar to a turbojet engine, for supersonic operation. This is accomplished while retaining the good subsonic performance features of a turbofan engine. A two-stream coannular nozzle shows potential to reduce jet noise to below FAR Part 36 without suppressors. Advanced burner concepts have the potential for significant reductions in exhaust emissions. In total, these unique engine concepts have the potential for significant overall improvements to the environmental and economic characteristics of advanced supersonic transports.

751087. Modern Aviation Turbine Fuel Handling Systems. J. R. McCoy, Air Force Aero-Propulsion Laboratory, Wright-Patterson AFB.

Air Force design criteria have been published for the pressurized hydrant fueling system, and the philosophy and operation of a typical system is described. The use of noncorrosive pipeline materials and the internal coating of storage tanks have contributed significantly to maintaining a high level of quality for aviation fuels. Experience with the use of fiberglass reinforced plastic pipe is discussed.

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751088. Predicting Propulsion Related Drag of Jet Aftbodies. Paul W. Herrick, Pratt & Whitney Aircraft Div., United Technologies Corp.

Two propulsion related drag correlation parameters have been developed. Existing or planned parametric jet aftbody drag data can therefore be reduced into a simple prediction technique for aircraft preliminary design studies. The drag due to the external nozzle geometry correlates with the average slope of the aftbody's area distribution (Integral Mean Slope), and the drag influence of the internal nozzle geometry/exhaust plume correlates with an effective plume inclination angle (Plume Correlation Parameter). The propulsion related drags of single, twin, and two-dimensional jet installations, and convergent, convergent-divergent, and plug nozzles are shown to

correlate with the two parameters. An example of the prediction system utilization is also presented.

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751089. The Transonic Jet Flap—A Review of Recent Results. H. Yoshihara, Convair Div., General Dynamics; and D. Zonars, Wright-Patterson Air Force Base.

Experimental results are used to explore the physical mechanism of lift augmentation and the drag due to lift, and to show the inadequacies of the Taylor-Spence thin jet model of the jet flap. In the jet-flapped wing-fuselage configuration, 3D effects, particularly due to the wing-fuselage interference, are shown to have major effects on the performance of the jet flap. At large sweeps the 3D vortical nature of the shock-induced separation is shown to also play a dominant role.

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751091. Aircraft Pay-Offs and Requirements for a Jet Flap Propulsion System. Stephen Mark Silverman, Rockwell International Corp.

Jet flaps, because of their propulsive lift characteristics, have the theoretical potential to improve fighter aircraft performance. Studies have shown that to achieve these improvements afterburning jet flaps are required. The benefits gained are primarily at high lift coefficients; consequently, there is a significant interaction between the jet flap effects and the wing aerodynamics. In order to integrate the jet flap into fighter designs, short afterburners are necessary. Titanium sandwich construction appears to be the best structural concept for a jet flap.

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751092. Propulsion Concepts for High Speed Aircraft. Frank D. Stull, Aero Propulsion Laboratory; Robert A. Jones, Langley Research Center, NASA; and William P. Zima, Air Force Flight Dynamics Laboratory.

A wide variety of potentially useful and effective air-breathing aircraft have been postulated to operate at speeds in excess of Mach 3.0 by NASA and the USAF. These systems include hydrogen-fueled transports of interest for very long ranges and airbreathing launch vehicles which are aircraft-type first stage candidates for future space shuttle systems. Other high speed airbreathing systems for possible future military applications include advanced reconnaissance and fighter/interceptor type aircraft and strategic systems. This paper presents (1) a chronology of Air Force technical activity on future propulsion concepts, (2) a status report on NASA research on scramjet technology for future systems which may require speeds above Mach 5, and (3) a description of a research vehicle by which advanced propulsion technology and other technologies related to high speed can be demonstrated.

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751093. Tank and Fuel Systems Considerations for Hydrogen Fueled Aircraft. G. Daniel Brewer and Robert E. Morris, Lockheed-California Co.

Commercial transport aircraft must be capable of operating worldwide; accordingly, a fuel of uniform and high quality must be available worldwide. Hydrogen is proposed as fuel for advanced design transport aircraft in the era subsequent to 1990 because of the problems of availability and cost forecast for conventional jet fuel derived from petroleum. The result of design studies to evaluate the feasibility, practicability, and potential advantages/disadvantages of using hydrogen as fuel in both subsonic and supersonic transport aircraft are summarized. The design requirements and characteristics of aircraft tank and fuel systems to satisfactorily contain and control liquid hydrogen fuel are described.

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751094. Efficiency and Economics of Large Scale Hydrogen Liquefaction. C. R. Baker, Linde Div., Union Carbide Corp.

Liquid hydrogen is being considered as a substitute for conventional hydrocarbon-based fuels for future generations of commercial jet aircraft. Its acceptance will depend, in part, upon the technology and cost of liquefaction. The process and economic requirements for providing a sufficient quantity of liquid hydrogen to service a major airport are described. The design is supported by thermodynamic studies which determine the effect of process arrangement and operating parameters on the process efficiency and work of liquefaction.

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751095. The Manufacture of Hydrogen from Coal. C. L. Tsaros, J. L. Arora and K. B. Burnham, Institute of Gas Technology.

As part of a study for the conversion of coal to fluid fuels, we have developed three process designs for the conversion of Montana subbituminous coal to hydrogen based on three different gasifier technologies.

1. Koppers-Totzek suspension gasification
2. U-GAS™ fluidized-bed gasification
3. Fluidized Steam-Iron Process

For comparison with methane from coal, a fourth design, based on the HYGAS® Process has been prepared. Nominal plant capacities are 250 billion Btu/day of product gas. Overall plant efficiencies for conversion of coal to major gaseous products plus by-products are:

Koppers-Totzek 57.0%

U-GAS 66.4%

Steam-Iron 62.6% (Includes 18% by-product electricity)

HYGAS 74.0%

Product liquefaction requirements are presented. Capital and operating costs (mid-1974) are presented for U-GAS and HYGAS. With coal at $0.30/million Btu, prices for hydrogen and methane are $2.17 and $1.77/mil-

lion Btu. Methane is more attractive in both efficiency and cost.

751097. Commercial Applications of Rocket Technology: The Charged Droplet Scrubber (CDS). H. L. Burge, W. Krieve, R. Koppang and M. Huberman, TRW Systems Group.

An electric propulsion research program funded by the Air Force has provided the technology basis for a new environmental control system called the Charged Droplet Scrubber. To date, the Charged Droplet Scrubber has demonstrated that it is a low-cost, highly effective method of removing particulates from industrial sources of gas pollutants. The Charged Droplet Scrubber was conceived during the early development of an electrostatic colloid thruster for low thrust propulsion of spacecraft. The thruster research program is managed by the Air Force Systems Command's Rocket Propulsion Laboratory and is conducted by TRW Systems Group. A joint venture company, with TRW and Mitsubishi Corp. as partners, is developing and commercializing the new scrubber device.

The colloid thruster operates by accelerating charged droplets through an electrostatic field. These droplets leave the thruster at a very high velocity, thus providing the small amount of thrust required for certain spacecraft operations, such as stationkeeping. The operating principle of the scrubber is similar to that of the colloid thruster; the primary difference is that charged water droplets are used to impact and collect dust particles instead of being discharged to provide thrust. The water containing the trapped particles is collected for subsequent treatment.

A comparison between the Charged Droplet Scrubber and the more conventional electrostatic precipitator, both operating at the same high collection efficiency, indicates that the new scrubber system requires less volume and lower first cost. Additionally, the power, and therefore the operating costs, are lower for the Charged Droplet Scrubber.

The Charged Droplet Scrubber program has advanced from laboratory evaluation, through pilot scale evaluations, to a total of seven commercial installations. During laboratory tests, a number of tests and industrial dusts were evaluated in a program to develop design data to assess the commercial feasibility of the concept. Subsequently, eight pilot scale systems were fabricated and installed in asphalt plants, pulp and paper plants, electric utilities, and steel mills. The results of these pilot scale tests met all technical objectives. To date, seven commercial installations have been completed and are in operation.

751100. Mechanically Coupled Lift Fan Propulsion and Control for Multimission V/STOL Aircraft. J. M. Zabinsky, P. Gotlieb and G. W. Jakubowski, Boeing Commercial Airplane Company.

A two-engine, three-fan V/STOL airplane was designed to fulfill naval operational missions. Use of interconnected variable pitch fans led to a good balance between the requirements for high thrust and responsive control at low speed, and efficient thrust at cruise speeds. Engine-out requirements, integration of propulsion and aerodynamic controls, and the propulsion installation were the major factors influencing the configuration. An airplane with a multimission capability from both vertical and short takeoff was conceived.

751101. How Requirements Influence the Lift/Cruise Fan Aircraft. L. E. Ames, McDonnell Douglas Corp.

Lift Fan Multimission V/STOL aircraft provide new capabilities which could revolutionize Naval and Marine aviation but the design concept as well as the design philosophy must be carefully selected. Since the propulsion system is the crux of any V/STOL aircraft this is of primary importance followed by secondary design considerations such as fuselage sizing to accommodate the multimission requirements.

751103. Vertical Attitude Takeoff and Landing Remotely Piloted Demonstration Vehicle. Warren H. Eilertson, David W. Taylor Naval Ship Research and Development Center.

Launch and recovery of RPV's aboard ship has been identified by the Navy as a major design impact area. Vertical attitude takeoff and landing offers attractive advantages to the Navy in that ship/RPV interface problems are alleviated. To assess these advantages the Aviation and Surface Effects Department at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) has designed and constructed a 560-lb. demonstration vehicle. This vehicle during FY-1976 will be flight tested to assess vertical hover capability of the RPV in the turbulent aerodynamic wake generated by a ships superstructure while underway.

The design incorporates a close coupled canard/delta wing configuration. Components from the MQM74A target drone as well as the Harpoon missile are utilized. Other Navy laboratories are cooperating in support of engine installation design and test (NWC), guidance and control (NUSC), power circuitry (NATC), and flight tests (PMTC). Flight tests in hover, horizontal flight, transition (at safe altitudes) and ship docking are planned.

751104. Three-Engine Two-Fan Navy Multimission V/STOL Aircraft Considerations. J. C. Ford, Los Angeles Aircraft Div., Rockwell International.

A three-engine, two-fan arrangement for an advanced vertical and short takeoff and landing (V/STOL) lift/cruise multimission aircraft has many advantages.

With three engines, sufficient engine-out thrust is available for safe operation, over the range of multimission emergency landing requirements. The flexibility offered by being able to shut down one engine for loiter and cruise results in a fuel-conserving aircraft. The capability to add the power of the third engine provides a

high-speed vehicle when the mission requires.

A two-fan system with fans under each wing provides for smooth transition from vertical flight to forward flight and return. Minimum-distance STOL performance is achievable because all of the thrust is available to accelerate the aircraft during the takeoff ground roll and to interact with the wing during climbout. In shaft-driven systems, clutching horsepower can be drastically reduced or eliminated. Fans can be made interchangeable. Maximum fuselage volume is available for payload and operational systems components. Wing-mounted pod arrangements provide good compatibility with such passenger-carrying configurations as vertical onboard delivery (VOD) and commercial aircraft.

751105. Improvements in VTOL Engineering Resulting from the U.S. Army HLH and YUH-61 Programs. W. Euan Hooper, Boeing Vertol Company.

For two decades the major engineering innovation and improvement in VTOL engineering was the introduction of turbine engines with consequent improvements in speed and payload performance. But in the last few years the VTOL industry has been introducing and implementing innovative engineering solutions to many long-standing helicopter deficiencies. A major influence in bringing about these changes has been the demands of the world's biggest user of helicopters, the U.S. Army, as defined in their specifications for the Heavy Lift Helicopter (HLH) and Utility Tactical Transport Aircraft System (UTTAS). This paper describes some of the substantial engineering improvements that have already been demonstrated in the Boeing HLH and YUH-61A programs and which will be seeing increasing application in production helicopters in the next decade.

751106. Rotor Technology for New Generation Helicopters. David S. Jenney, Sikorsky Aircraft, ABC Program.

The helicopter industry in the United States is in the process of developing a whole family of new helicopters — a second generation of turbine powered helicopters offering significant improvements over their predecessors. Much of the progress that makes the new helicopters better is in their rotor systems. This paper reviews the benefits provided by new materials and new concepts employed in four rotors systems that are in various stages of development at Sikorsky Aircraft.

The titanium-spar blades used on the CH-53E and YUH-60A (UTTAS) take advantage of the high strain allowable of that material to permit aerodynamic optimization for both high speed cruise capability and unmatched hovering performance. A little further down the development ladder, the use of carbon/fiber glass composites for the main spar retains the flexibility for aerodynamic design while further reducing rotor weight and promising a substantial reduction of blade costs. The use of advanced composites is carried to its full potential in the composite bearingless rotor. In this concept, already flying as the UTTAS tail rotor, the anisotropic properties of composites are used to eliminate all conventional bearings (flap, lag and pitch). Finally, the ABC rotor with its unique aerodynamic advantages and structural requirements provides an ideal application for new materials. While titanium spars on the current demonstrator have made it possible to evaluate the concept, advanced composites should provide weight and cost reductions to make the concept even more attractive.

751107. Metal/Composite Hybrid Rotor Blade Spar Construction. Peter A. Reyes and Max Glass, Bell Helicopter Company.

Unidirectional fiberglass straps are investigated as a means of providing metal rotor blades with a redundant load path and reduced fatigue crack growth rate. A comparison of crack growth rates for a metal/composite hybrid spar and a conventional metal blade structure are shown. Comparisons of ballistic impact damage for the hybrid spar and the metal spar are presented. Additionally, the results of small-specimen fatigue tests to investigate void propagation at the glass/metal interface are discussed.

751108. Composite Structures—Technical Breakthrough for Helicopter Rotor Blades. L. L. Douglas and W. K. Stratton, Boeing Vertol Co.

In this decade we are witnessing the transition from all metal to all composite helicopter rotor blades. One such helicopter is already in full scale production. A driving factor is structural reliability and guarantee against catastrophic failure. Low crack propagation rate and the nature of failures in composite structures are the characteristics which make this quality product superior to metal structures for rotor blades. The ability to economically tailor blades aerodynamically and dynamically offer important advances in performance, flying qualities, low stress levels, and low vibratory forces.

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751109. Remotely Piloted Vehicle Technology Development Using the XQM-103 Research Test Vehicle. Thomas L. Larsen, Wright-Patterson Air Force Base.

Recent advances in electronics have enabled the Air Force to consider using remotely piloted vehicles (RPVs) for missions into areas too heavily defended for manned aircraft to penetrate. This paper describes the RPV technology development program using the XQM-103, an extensively modified Model 147G drone. The vehicle and its associated control system are being used to conduct quantitative flight tests involving vehicle performance improvements, remote piloting techniques, and application of RPVs to various operations.

A complete description of the XQM-103 system is provided, including special emphasis on the Remote Pilot Station, the Flight Control System, the Command/

Telemetry System, and the Video System. Results of the Phase I Flight Test Program, as well as plans for Phases II and III are presented.

751110. Teleplane and Mini-RPV Technology. Donald T. Lowe, Wright-Patterson Air Force Base.

The Air Force Project "Teleplane" was established for the purpose of developing RPV Technology at low cost. The approach taken through the use of small inexpensive remote controlled aircraft has proven to be useful and has helped establish the credibility of Mini-RPVs as military weapons.

751113. RPV Autoland. Aivars Smitchens and Robert R. Huber, Wright-Patterson Air Force Base.

An automatic takeoff and landing system has been developed for remotely piloted vehicles (RPV) operating from prepared runways. This system consists of a scanning beam microwave landing guidance system and a high performance flight control system. Interfaced with the automatic system is a remote operator, who, using a special control station, monitors system performance, evaluates approach quality and may remotely control the vehicle in the event of contingencies.

This paper describes briefly the RPV Automatic Takeoff and Landing (Autoland) system development program: the design approach, simulation and flight test results, and conclusions.

751114. Component Performance and System Payoff for Advanced Internal Power Generation Unit. F. J. Suriano, AiResearch Manufacturing Co. of Arizona, div., Garrett Corp.

The overall growth in aircraft internal power system requirements has dictated that a key part of that system, the small gas turbine internal power engine, become a high performance engine in terms of horsepower per engine cubic foot and pound. These performance levels must be met while facing unique problems attendant with internal power applications. Some of these problems are demonstrated by examining the engine performance influence coefficients of a USAF advanced internal power generation engine and comparing with those of a larger propulsion engine.

751117. Low Cost Jet Fuel Starter. R. Smith, Teledyne CAE.

This paper presents the results of a design study of a low cost Jet Fuel Starter (JFS). The JFS is a small free turbine turboshaft engine with a peak output of 150 horsepower. The design concentrates on high output per unit volume and weight, and on low cost. A low speed, four stage axial compressor design results in a compact, lightweight starter. Die castings and a radial pin construction for both the static structure and the compressor rotor provide the most significant cost savings over conventional gas turbine fabrication methods. The low speed concentric shaft design (approximately 70% of usual design practice) permits a simple two bearing shaft suspension for both rotors. The resulting close coupling of the turbines reduces the number of expensive hot end components to only five parts.

751118. An Aerodynamic Torque Converter for High Speed Coupling of an Auxiliary Power Unit. J. J. Edwards and J. L. Myers, Rohr Industries, Inc.

An Aerodynamic Torque Converter (ATC) which operates as a high speed coupling device between a single shaft auxiliary power unit (APU) and the accessory loads has been designed and built, and is in the latter stages of its testing program. The ATC operates at APU speeds and temperatures while maintaining favorable power-to-weight and power-to-volume ratios.

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751119. Correlation Between Smoke Measurements and the Optical Properties of Jet Engine Smoke. Allen D. Wood, Lockheed Palo Alto Research Laboratory.

The smoke production of aircraft gas turbine engines is currently characterized by the SAE smoke number and, to a lesser extent, the exhaust transmittance. Quantitative relationships are developed between these characterizations and the optical properties of the engine smoke particles for use in subsequent visibility calculations. These optical properties are the particulate mass concentration and the specific projected particle extinction area.

The SAE smoke number is both the most common smoke characterization and the one farthest removed from optical properties. The inherent stained filter technique is first treated in general, then specifically in terms of the SAE requirements. A relation between the smoke number and the optical properties is achieved. It is shown that the SAE interpolation procedure is unsuitable at low smoke numbers, and an alternative procedure is suggested.

A relation between smoke number and exhaust transmittance is derived which agrees well with experimental data. Next, the optical properties obtained in this work are compared against the one experimental measurement and a theoretical result using Mie theory. The overall agreement is quite good. Particulate agglomeration is considered and shown to have a negligible effect on the optical properties.

Finally, the results are summarized both in words and in graphical form. It is recommended that exhaust transmittance, which is directly related to the smoke visibility, become the industry standard for quantifying smoke emission from aircraft gas turbine engines.

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751120. (SP-398) **Powerplants—Past, Present and Future.** Gerhard Neumann, General Electric Company.

The rapid and dramatic growth of aviation over the past several decades is a matter of history with which we are all quite familiar. Integral to that growth has been the

mushrooming progress in powerplant technology which, by necessity, is the lead factor in the development of aircraft systems.

This paper highlights some of the major milestones that have influenced the course of developments in gas turbine powerplants. It traces its origins in work done on turbo-superchargers, with discussion of the stimuli and shifts in requirements that resulted in various types of jet engines leading up to today's high-bypass turbofans. The natural quest to fly higher, faster and further has reached a point of relative maturity in technology so that today's efforts can now be directed more towards improvements in efficiency, reliability and ecological consciousness.

The future holds new challenges. It calls for new ways to control the spiraling costs of development and production of powerplants. In the face of higher and higher fuel costs, there is a need to continuously strive for lower fuel consumption, and at the same time, to study alternate sources of energy for gas turbines. And there is much yet to be done in making engines as clean and as quiet as the public demands.

Because today's climate is characterized by fewer new product opportunities, diminishing support for research and development, and cost/price inflation affecting both the manufacturer and customer, technology progress in the future may be less spectacular than in the past, but will be just as meaningful and beneficial to the future of aviation.

751141. (P-62) **Three-Point Belt Induced Injuries: A Comparison Between Laboratory Surrogates and Real World Accident Victims.** J. Robert Cromack and H. Haskell Ziperman, Southwest Research Institute.

Injuries produced by standard three point restraint systems with retractors will be compared between cadavers in laboratory simulated collisions at 30 mph barrier equivalent speed and lap and shoulder belted front seat occupants in real world frontal collisions of'73-'75 full sized cars. Tests conducted at SwRI with belted, unembalmed, fresh cadavers have resulted in extremely severe thoracic and cervical injuries, including multiple rib fractures, fractures of the sternum, clavicle and cervical vertebrae. On the other hand, injury data from a national accident investigation study to evaluate the effectiveness of restraints in late model passenger cars indicates that such injuries in real world crashes of equivalent severity are not always observed. The reasons possible for these differences are discussed. Both programs at SwRI are funded by the National Highway Traffic Safety Administration.

751142. (P-62) **Efficiency Comparison Between Three-Point Belt and Air Bag in a Subcompact Vehicle.** M. Dejeammes and R. Quincy, Laboratore des Chocs Organisme National de Sécurité Routière (Onser) France.

The purpose of this paper is the comparison of the protection efficiency between three-point belt and air bag systems under various crash conditions.

Dynamic tests have been performed with subcompact vehicles (Renault R 12) in which two dummies were restrained, either by three-point belts with load limiting devices, or by air bags consisting of solid gas generators and bags including porous outlets (the driver's knees were protected by a collapsable structure).

Three types of crashes were chosen: frontal barrier crash at 50 km/h (13,9 m/s); head-on crash between two vehicles with overlap at 50 km/h (13,9 m/s); crash against a guardrail at 80 km/h (22 m/s) with 30° angle of incidence.

The comparison drawn from commonly used biomechanical indices shows that the three-point belt ensures a protection in each analysed crash type but it should be improved in order to reduce head deceleration. The air bag results depend on the crash type and show the problems of adaptation in a subcompact vehicle.

The frontal barrier crash tests conducted with another type of dummy reveal that the results obtained for the two restraint types depend on the dummy, so that the efficiency assessment is difficult.

751143. (P-62) **Injury Patterns by Restraint Usage in 1973 and 1974 Passenger Cars.** Joseph C. Marsh, R. E. Scott and John W. Melvin, Highway Safety Res. Inst., University of Michigan.

Data on towaway accidents involving 1973- and 1974-model American passenger cars were collected according to a systematic sampling plan in order to measure 1974 restraint system performance. The data on 5,138 drivers and right front passengers were collected by three organizations: Calspan Corporation, Highway Safety Research Institute, and Southwest Research Institute. Analysis of the data showed that the 1974 ignition interlock system increased full restraint system usage by a factor of 10 over 1973 cars. The 1974 full restraint system (lap and upper-torso belts) also demonstrated a greater reduction in severe injuries ($AIS \leq 2$) than the 1973 lap-belt-only system. Paradoxically, little reduction in 1974-model severe injuries was found when the two model years were compared, although no attempt was made to control for confounding factors in the accident cases.

Injury patterns were explored in terms of the rate of occurrence of specific injuries by body region, lesion, and injury source. All restrained occupants sustained a lower rate of specific injuries than unbelted occupants, and fully restrained occupants had a greater probability of receiving fewer injuries than lap-belted occupants. Restrained occupants received fewer head, face, extremity, and chest injuries and more neck, abdomen and pelvis injuries. The rate of face injuries with full restraints was half the rate of lap-belt-only occupants. Full restraints also reduced the incidence of steering-assembly and front-interior injuries but did not eliminate them.

751144. (P-62) **Injury to Unembalmed Belted Cadavers in Simulated Collisions.** L. M. Patrick, College of Engineering, Wayne State University; and R. S. Levine, School of Medicine, Wayne State University.

Unembalmed cadavers restrained with a three point harness were exposed to a deceleration environment of 20, 30 and 40 mph BEV. Injuries were tabulated from detailed autopsies. The results indicate an AIS-1 injury at 25.5 mph, an AIS-2 injury at 31.5 mph and an AIS-3 injury at 34.5 mph. The AIS-3 injury level is recommended as the maximum acceptable injury.

The cadavers sustained the same types of injury that have been reported in medical literature including bruises, abrasions, lacerations, fractures and viscera ruptures, but injury severities were greater in the cadavers than in living humans at a given collision severity. Also, there is a wide spread in the degree of injury between cadavers due to differences in age and physical condition. The threshold of cadaver rib fracture is 30 mph and the threshold of cadaver vertebral fracture is between 30 and 40 mph for the environment utilized.

More numerous and severe abdominal injuries were observed. They were attributed to excessive submarining as a result of no restraint from the instrument panel and leg muscles of the cadavers. It is concluded that the cadaver is an excellent means of studying the types of injuries to be expected from a collision environment.

751145. (P-62) **The Impact Behavior of the Hybrid II Dummy.** Roger P. Daniel, Kenneth R. Trosien and Burgess O. Young, Ford Motor Company.

The head, chest and femurs of three Hybrid II dummies were impacted with a ballistic pendulum at various angles to determine what differences in accelerometer and femur load cell output would result for a constant energy input. Also evaluated were suspicious tension loads in the femur load cell output when the legs were subjected to obvious off-center impacts during crash tests. It was found that the dummy legs can be subjected to very high torsion and bending loads which can have a significant effect on the femur load cell axial load outputs.

751146. (P-62) **Motion Sequence Criteria and Design Proposals for Restraint Devices in Order to Avoid Unfavorable Biomechanic Conditions and Submarining.** Dieter Adomeit and Alfred Heger, Institute of Automotive Engineering, Technische Universität Berlin.

Our aim is to show that today's safety standards (FMVSS 208, EC-Proposals) are inadequate in the present state to ensure optimum protection for belted passengers. These standards do not take into account motion sequence during impact. The postulated tolerance limits - HIC, SI, forward displacements etc. - cannot describe the dynamic behaviour adequately.

We emphasize the importance of motion sequence to ensure optimum biomechanic conditions, because motion sequence is the necessary prerequisite for any discussion about biomechanical tolerance limits.

First results of our current belt-accident-investigations indicate that this is an important problem. By applying experience from crash tests and accident investigations, we try to define simple and well controllable criteria for motion sequence. These criteria should not only guarantee favourable biomechanical loads for the belt-restrained passenger, but also give the possibility of simplifying data registration and calculation of results.

Our final aim is to reduce belt-specific injuries, since they are avoidable by using current technical capability.

The solution of these problems can be achieved by modifications of safety standards using defined motion sequence criteria. This would lead to further developments of the system comprising a 3-point-belt and the seat.

In this paper we introduce one possible development. Results of a number of crash tests show its efficiency.

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751147. (P-62) **Comparison Between In-The-Field Accidents and Reconstructed Accidents with Dummies and with Cadavers.** D. Cesari and M. Ramet, Laboratoire des Chocs et de Biomecanique, Organisme National de Securite Routiere (Onser) France.

By accurately reconstituting accidents whose parameters are well known from multidisciplinary accident investigation, it is possible to associate forces and accelerations values with injuries sustained by occupants involved in in-the-field accidents.

In this study, two in-the-field accidents, their reconstruction conducted by using dummies as occupants, and their reconstruction then with human cadavers are analysed.

These accidents reconstructions allow to associate and compare accident occupants injuries with acceleration forces, injuries criteria values measured on dummies, and, on the other hand, accelerations, injuries criteria values, injuries sustained by cadavers during the second accident reconstruction.

751148. (P-62) **Thorax of 3-Point Belt Wearers During a Crash (Experiments with Cadavers).** A. Fayon, C. Tarriere and G. Walfisch, Laboratory of Biomechanics and Physiology, Peugeot-Renault; C. Got and A. Patel, I.R.O., Raymond Poincare Hospital - Garches.

This paper deals with frontal crash simulations with 3 point seat-belts, in which the conventional anthropomorphic test dummy has been replaced by a fresh unembalmed cadaver. Numerous test conditions have been used.

Here are the complete results on the thorax for 31 cadavers in dynamic tests and 7 others in static tests.

Specific interest in the thorax comes from the examination of injuries which has shown that, for a normal test, severe injuries are seldom located elsewhere

than in the thorax.

Methodology, which is the first described, states in particular how the cadavers are prepared with reconstitution of blood pressure and lung inflation and how skeleton strength is characterized.

Among the results shown are those for the thorax autopsies, the corresponding seat belt restraint forces, some measurements with dummies used simultaneously and some data on recorded thorax deflections.

Injuries observed when carrying out the autopsies are compared with the measurements (forces, accelerations, deflections) made on cadavers and dummies, and with previously published data.

The difference between tolerance to impact and to belt forces is pointed out. Some data which might help to define a dummy thorax is included.

751149. (P-62) **Neck and Thorax Tolerance Levels of Belt-Protected Occupants in Head-On Collisions.** G. Schmidt, D. Kallieris, J. Barz, R. Mattern and J. Klaiber, University of Heidelberg (West Germany).

Our tests with fresh human cadavers were continued (cf. Proceedings, 18th Stapp Car Crash Conference). Presented herewith are the results of 103 tests evaluated so far.

While the severity of injuries showed an increase with advancing age, it is not obviously dependent upon weight or sex. Under the conditions chosen by us, the 12 to 30-year age group reached the thorax tolerance level at an impact velocity of still below 50 km/h with a stopping distance of 40 cm, the 30 to 50-year age group of below 40 km/h, and the age group beyond 50 years of below 30 km/h.

A comparison of our results with volunteer tests and with evaluated real accidents as well as with similar cadavar tests is made. When introducing safety testing regulations for vehicles in the light of dummy tests, the broad spectrum of the respective age groups has to be considered. The thorax injuries may be slightly mitigated due to a lessening of the surface pressure. The injuries of the neck and thoracic vertebra, on the other hand are apparently not dependent on this factor and to a varying extent, are always occurring at an impact velocity of 50 km/h. Here too, the severity of the injuries increases according to the age.

Therefore, it was set great store by the recording of vertebral injuries. By employing careful dissection and preparatory-techniques, disc injuries, hemorrhages in the region of muscles and intervertebral joints were found in the majority of the cases, where as less frequently fractures of vertebral bodies, vertebral arcs and fractures of the processus spinosus and transversus, respectively were noticed. Highly dangerous vertebral injuries involving contusion or rupture of the cervical or thoracic spinal cord occurred only rarely. The Abbreviated ACIR scale proved to be sufficient for the graduation of the injuries. The grades ranging from 0 to 4 may well be compared with the AIS scale with grades from 0 to 9 (AIS 6 - 9 = fatal is equivalent to ACIR 4). States and Huelke suggest the simplification and reduction of the AIS scale. They recommend a condensation of figures 6 - 9, thereby approaching the ACIR scale. By measuring the bone hardness and bending strength of the ribs, the skeleton injuries observed in the tests were related to the age-dependent resistance capability.

In concluding, reports will be rendered on the photographic ebaluation of the phases of movement recorded laterally by a high-speed camera, and on the legal basis of cadaver tests.

751150. (P-62) **Cadaver Skeletal Response to Blunt Thoracic Impact.** Alan M. Nahum, Department of Surgery, University of California, San Diego; Dennis C. Schneider and Charles K. Kroell, Biomedical Science Department Research Laboratories, General Motors, Corp.

Sternal and/or spinal acceleration data from eighteen of the unembalmed cadaver, blunt thoracic impact experiments reported by the authors at the Eighteenth Stapp Conference have been analyzed and several related response parameters computed.

High acceleration levels, rates of onset, and Gadd Severity Indices were found in sternal acceleration measurements, whereas quite low values were obtained from the spinal regions in the same tests. A Severity Index value of 1000, computed from a sternal acceleration measurement, would be associated with only a mild exposure; whereas for a spinal measurement, the same value would reflect an extremely severe exposure.

Correlation matrices which include cadaver characteristics, input and response parameters, and Abbreviated Injury Scale ratings show that none of the sternal acceleration parameters correlate well with AIS rating in the analyzed data base. Maximum spinal velocity and spinal Severity Index both indicate good correlations with AIS rating; but because of an obvious dependence on the degree of body restraint, they are regarded as less broadly applicable and, therefore, less useful than normalized chest deflection for the indication of severity of thoracic impact exposure.

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751151. (P-62) **Prediction of Thoracic Injury from Dummy Responses.** Raymond F. Neathery, Charles K. Kroell and Harold J. Mertz, Biomedical Science Department Research Laboratories, General Motors, Corp.

Currently used criteria based on functions of spinal acceleration obtained from crash test dummies are shown to be invalid indicators of chest injury in blunt frontal impacts. Cadaver impact data are analyzed; and injury is found to be a statistically significant function of chest deflection, chest depth, and cadaver age at death. Based on the resulting regression equations, injury-limiting chest deflections are recommended for various size test dum-

mies. The recommendations apply only to test dummies that have significant thoracic biofidelity for blunt frontal impact. They are valid for environments which include significant blunt frontal impact. Their extension to other environments has not been validated.

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751152. (P-62) **Frontal Crash Evaluation Tests of a Five-Point Harness Child Restraint.** Richard M. Schreck, Biomedical Science Department Research Laboratories, General Motors, Corp.; and Lawrence M. Patrick, Biomechanics Research Center, Wayne State University.

Tests were conducted to provide information on the mechanics of child restraint with a five-point harness system. For anatomical reasons, the juvenile chimpanzee was chosen as the best approximation to the human child. Sedated juvenile male chimpanzees withstood frontal deceleration tests in a five-point harness at crash speeds of 32.2, 40.2, and 48.3 km/h (20, 25, and 30 mph) without skeletal bone fractures or evidence of soft tissue injury. Injury assessment was by X-ray and blood serum enzyme analysis as well as ECG readings and post-test observations of the animals' behavior. While this animal model does not fully guarantee the identical performance of a five-point harness system with humans, these results support the opinion that the protection offered a child occupant in a five-point system is comparable to that available to adult passengers in conventional automotive restraint systems.

751153. (P-62) **Performance Evaluation of Child Dummies and Baboons in Child Restraint Systems in a Systematized Crash Environment.** Stanley H. Backaitis, Jere W. Medlin, Jr. and Vladislav G. Radovich, National Hwy. Traffic Safety Admin., Dept of Trans., Richard L. Stalnaker, Hwy. Safety Res. Inst., University of Michigan; Mahesh P. Shah, Transportation Res. Ctr.; John T. Shaffer and Robert M. Letscher, 6570th Aerospace Med. Res. Lab.

A three-part program was undertaken to establish an appropriate means of evaluating child restraints in automobile crashes.

A standard seat was designed to provide a reproducible test base on which to evaluate child restraint systems in dynamic testing. Developmental and evaluation data are presented, including child restraint performance tests. Results showed the standard seat to be a durable, repeatable, and economical test platform which provides a realistic base for evaluation of child restraint systems.

Commercially available three- and six-year-old child dummies were evaluated for their anthropometric measurements and dynamic response characteristics in pendulum impact tests and simulated crashes in representative automobile-child seat restraint environments. Simulated crashes included 20- and 30-miles-per-hour (mph) frontal and 20-mph side impacts on automobile and specially designed bench seats. Two types of child seats, the G.M. "Love Seat" and Chrysler "Mopar," were selected for testing as representative of belt and padding restraint types currently in use.

The three-year-old child dummies were found to be capable of providing repeatable measurements of the head and chest accelerations and head deflections in sled tests and to be sufficiently sensitive of detecting differences in the crash environments. Acceleration measurements on both six-year-old child dummies were found to contain resonances.

An extensive sled testing was performed with child restraint systems to determine which of the two types of dummies simulate best the in-vivo response of primates and what criteria may be employed to measure the dummy response and the efficacy of child protection systems. Test results indicate that the mechanical test dummy, consisting of clearly defined adjustable body segments, is a better simulator than the lumped mass unadjustable type. Test results also indicate that current instrumentation technology for application to in-vivo subjects is not adequately developed to permit consistent measurements in terms of "G" levels, injury criteria, etc. A better correlative measure between primates and mechanical child dummies is the head excursion, in both the forward- and lateral-collision modes. This is, however, limited to the first collision phase and is not valid for the rebound phase. The tested shield-type child restraint exposed the occupant to potential risk of ejection during the rebound mode of the forward-collison phase and to substantial excursion in lateral collisions if the seat does not have provisions for limiting the lateral motion of the test subject.

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751154. (P-62) **Car-to-Car Side Impacts: Computerized Crash Reconstruction.** August L. Burgett and Michael W. Monk, National Highway Traffic Safety Administration, U.S. Department of Transportation.

This paper describes the injury relations which result when car-to-car crashes are analyzed using a computerized accident reconstruction procedure.

The results of the study are presented in the form of graphical relations between injury severity and crash severity. Effects of factors such as impact location, seating position and vehicle weights are discussed.

751155. (P-62) **Simulated Occupant Response to Side-Impact Collisions.** B. M. Bowman, L. W. Schneider and D. R. Foust, Highway Safety Research Institute, University of Michigan.

Occupant response to side-impact collisions is studied with a mathematical vehicle/occupant model, the MVMA Two-Dimensional Crash Victim Simulator. A primary goal is the investigation of head-torso relative motion and neck forces and moments. Computer simulations were

performed in conjunction with a study on properties of the neck in lateral motion (not reported on here) involving 96 subjects. The subject pool consisted of six carefully defined population segments which represented young, middle-age, and elderly male and female adults of average stature. The side-impact simulations make use of much pertinent data resulting from the volunteer subject testing program, including head-neck lateral bend range of motion, sternomastoid muscle group strength, reflex time, and anthropometry. For the various population segments, the series of computer simulations investigates 10- and 30-mph car-to-car impacts, the effect of muscle reflex with muscle tension buildup, and the effect of varying degrees of pre-impact constant tension. It is determined that neck muscle contraction may significantly lessen the likelihood of hard-tissue injury resulting from excessive lateral flexion. The lesser muscular strength of female and elderly crash victims indicates greater susceptibility to neck injury for these groups.

751156. (P-62) **Biomechanical Properties of the Human Neck in Lateral Flexion.** Lawrence W. Schneider, David R. Foust, Bruce M. Bowman, Richard G. Snyder, Don B. Chaffin, Thomas A. Abdelnour and Janet K. Baum, University of Michigan.

Properties of the human neck which may influence a person's susceptibility to "whiplash" injury during lateral impact have been studied in 96 normal subjects. Subjects were chosen on the basis of age, sex, and stature and data were grouped into six primary categories based on sex (F,M) and age (18–24, 35–44, 62–74). The data include: measures of head, neck and body anthropometry in standing and simulated automotive seating positions, three-dimensional range of motion of the head and neck, head/neck response to low-level acceleration, and both stretch reflex time and voluntary isometric muscle force in the lateral direction. Reflex times are found to vary from about 30 to 70 ms with young and middle aged persons having faster times than older persons, and females having faster times than males. Muscle strength decreases with age and males are, on the average, stronger than females. Range of motion was determined by using three-dimensional photogrammetry to compute Euler angles relative to the Frankfort plane. Ranges of motion are reported for 6 planar movements (flexion, extension, left and right rotation, left and right lateral bend) and 3 combination movements (left rotation plus flexion, left rotation plus left lateral bend, and right rotation plus extension) chosen to simulate typical lateral impact conditions. For the young subjects, ranges of motion for males and females are similar. In all cases the range of motion decreases with age, with the rate of decrease for males being greater than that for females. Data are presented in a format applicable to biomechanical modeling of the seated human occupant.

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751157. (P-62) **The Effect of the Initial Position of the Head and Neck on the Dynamic Response of the Human Head and Neck to -Gx Impact Acceleration.** C. L. Ewing, D. J. Thomas, L. Lustick, E. Becker, G. Willems and W. H. Muzzy III, Naval Aerospace Medical Research Laboratory Detachment.

In preparation of an analog of human head and neck, the reports by R. G. Snyder and others were noted which stated that initial position of the head and neck had a definite effect upon resulting response. An investigation was undertaken to attempt to quantitate this effect, as a part of a much larger study underway for several years.

Thirteen human volunteer subjects ranging from the 5th to the 97th percentile in sitting height were exposed to -Gx impact acceleration at peak sled accelerations of 6G and 10G. Two angles of the neck relative to chair and two angles of the head relative to the neck for a total of four conditions were tested for each subject for the 2 peak acceleration levels giving a total of 104 experiments. Instrumentation consisted of 6 accelerometers and two-axis rate gyro at the posterior spinous process of the first thoracic vertebral body, 6 accelerometers at the mouth, and a two-axis rate gyro at the top of the head. Three-dimensional photography from two orthogonally mounted onboard cameras was used also.

The input data at T_1 along with the differential effects of initial head position relative to T_1 on the linear acceleration at the origin of the head anatomical coordinate system and on the angular acceleration and angular velocity of the head will be presented along with the implications for modeling the response and a statistical comparison.

751158. (P-62) **Static Bending Response of the Human Lower Torso.** Gerald W. Nyquist, Biomedical Science Department Research Laboratories, General Motors Corp.; and Clarence J. Murton, Biomechanics Research Center, Wayne State University.

This report defines humanlike quasi-static bending response characteristics of the lower torso. Six volunteers were subjected to a total of 72 tests to define response characteristics for sagittal flexion and extension bending. The effects of muscle tensing and knee bend on the response are evaluated. Sixteen loading corridors of moment of applied force about the H-point axis versus thorax-pelvis and pelvis-femur angles are suggested. The significant differences between the relaxed and tensed muscles results illustrate the need for a philosophical decision regarding which of these conditions should be adopted to define lower torso bending response for the human surrogate used in automotive safety studies.

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751159. (P-62) **Impact Response and Tolerance of the Lower Extremities.** John W. Melvin, Richard L.

Stalnaker, Nabih M. Alem, Joseph B. Benson and Dinesh Mohan, Biomechanics Department, Highway Safety Research Institute, University of Michigan.

This paper presents the results of direct impact tests and driving point impedance tests on the legs of seated unembalmed human cadavers. Variables studied in the program included impactor energy and impact direction (axial and oblique). Multiple strain gage rosettes were applied to the bone to determine the strain distribution in the bone.

The test results indicate that the unembalmed skeletal system of the lower extremities is capable of carrying significantly greater loads than those determined in tests with embalmed subjects (the only similar data reported in the present literature). The strain analysis indicated that significant bending moments are generated in the femur with axial knee impact. The results of the impedance tests are used to characterize the load transmission behavior of the knee-femur-pelvis complex, and the impact test results are combined with this information to produce suggested response characteristics for dummy simulation of knee impact response.

751160. (P-62) **Cadaver Femur Responses to Longitudinal Impacts.** William R. Powell, Steven J. Ojala, Sunder H. Advani and R. Bruce Martin, West Virginia University.

Results from longitudinal impact tests on the knees of nine seated cadavers are reported. Typical impact velocities, impact force histories and femur strain histories are presented. The importance of femur bending is revealed by strain readings on the medial, lateral, anterior and posterior surfaces. The effects of impactor padding, leg tissue and oblique impacts are illustrated. The average fracture force level was found to be 10.04 kN and the impact energy to be 549J. The fracture patterns and possible mechanisms are discussed.

751161. (P-62) **Transient Structural Response of the Linear Skull-Brain System.** T. A. Shugar, Civil Engineering Laboratory, NCBC.

The results of a head injury model development program are presented. They include a description of the model's features and its capabilities for simulating direct and indirect impact forces. The model's validity is discussed in terms of level of confidence and verification, Skull bone response and brain response are presented for a variety of dynamic simulations. The scope and limitations imposed by the assumption of linearity are discussed. The results demonstrate that while some minor changes appear indicated, the model predictions yield useful insight into the mechanical causes of skull and brain injury.

751162. (P-62) **On the Use of the Head Injury Criterion (HIC) in Protective Headgear Evaluation.** James A. Newman, Mechanical Engineering, University of Ottawa.

The validity and appropriateness of the application of the Head Injury Criterion (HIC_m) concept to motorcycle helmet testing has been examined. Its derivation has been reviewed and its logic assessed. It is shown to be an inconsistent and unreliable criterion for helmet performance evaluation. This inconsistency stems primarily from its poor correlation with experimental data and from the basic assumption that the seriousness of a head impact can be ascertained by considering only a portion of the test headform acceleration pulse. Several alternative criteria which all are physically sound and mathematically consistent and which are more amenable to protective headgear design and testing are proposed. These criteria include force and loading time minimization; load distribution; minimization of loading rate and maximization of energy dissipation.

751163. (P-62) **The Development of a Detailed Finite Element Brain Model.** Carley Conrad Ward and Robert B. Thompson, Civil Engineering Lab., Navel Construction Battalion Center.

A finite element model of the human brain is developed which provides badly needed new information and insight in brain dynamics. The model is based on fewer assumptions and has sufficient detail to permit correlation with experiments. It demonstrates a new approach to brain modeling and hopefully it will become a useful tool in future research.

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751164. (P-62) **Head Space Requirements for Seat Belt Wearers.** David C. Herbert, John D. Stott and Christopher W. Corben, Traffic Accident Research Unit, Dept. of Motor Transport (Australia).

Investigations in New South Wales of passenger car crashes involving the death of wearers of lap/sash belts have led to the conclusion that head impact with a rigid part (usually in the side) of the occupied car is responsible for more deaths than any other impact.

The experimental work reported in this paper consists of crash simulations to map the space swept by the head of a lap/sash belted occupant, in head-on and in a range of side impacts in which no invasion or loss of head space occurs. The simulations employed an Ogle-MIRA dummy which has a very compliant thorax, modified with the stacked ball joint neck from a Sierra 1050 dummy, this combination having been shown to closely reproduce head motion of human volunteers in frontal crashes reported in the literature. The work includes validation of the dummy and an investigation of the influence on head space of the angle of crash, of inertia reels in the sash straps, and of seat springing, in contrast to the hard seats used for the volunteer crashes. The results provide evidence of the value of increasing head space so as to reduce the likelihood of head impact of otherwise well restrained occupants of passenger cars.

Three current model cars are tested for availability of

head space which is found to be inadequate, especially in front corner impacts on the occupant's side of the car, involving about 22° impact yaw.

751165. (P-62) **Pedestrian Vehicle Accident Simulation Through Dummy Tests.** Martin Kramer, Institute of Automotive Engineering, Berlin Technical University.

Pedestrian-vehicle accidents have become a peculiar urban problem that has to be solved in the future. This demands a better knowledge about the performance of pedestrian accidents. Tests using dummies to simulate real world accidents are very important to study the mechanism of impacts. Since only the dummy has been fitted with measuring devices like accelerometers, it is highly difficult to estimate the interaction between the dummy and the car to a fair degree of accuracy. Therefore, it is necessary to measure the body forces in addition to the dummy accelerations in order to explain the impact mechanism more precisely.

For this purpose, a body force measuring test vehicle has been developed at the Institute of Automotive Engineering, Berlin. A deformable unit which simulates the stiffness and geometrical measurements of a vehicle front is supported by load cells. The complete assembly is fixed on a very stiff chassis which allows to measure the resulting impact forces by magnitude and direction during the impact.

In this study two geometrical parameters (height and slope of the motor hood) have been varied to see their influence on the impact severity. The used front shape was a rounded pontoon type which is similar to small European cars. The results of some 20 test runs demonstrate that the described test installation is indeed a useful research instrument to study the influence of the design parameters of the car front on the impact performance and to evaluate their effect on the injury mechanism more precisely.

751166. (P-62) **Experimental Study of Pedestrian Injury Minimization Through Vehicle Design.** H. B. Pritz, C. R. Hassler, J. T. Herridge and E. B. Weis, Jr., Battelle, Columbus Laboratories.

The overall objective of this experimental investigation of pedestrian/vehicle impacts was to conduct representative impacts of unembalmed cadavers in order to (1) pioneer the establishment of impact tolerance levels for the pelvis and legs of a standing pedestrian and (2) explore the ability of a few selected geometry and compliance modifications to the impacting vehicle to increase the impact velocities that can be tolerated. A series of 15 experimental impacts were conducted which covered a speed range from 10 to 30 mph. Dynamic data obtained included high-speed films and time histories of (1) bumper and hood edge forces, (2) horizontal and vertical ground reaction forces, and (3) pelvic acceleration. The resulting injuries were determined from examination of pre- and post-impact X-rays and detailed pathological dissections, and were assessed as to probable temporary total and permanent partial disabilities. Three of the key results are that (1) injuries to the lower body of an adult pedestrian are strongly dependent upon vehicle design, (2) the pedestrian leg injury mechanism is a complex dynamic event influenced significantly by both the bumper force and the ground friction force, and (3) a threshold tolerance value of pelvic acceleration appears to exist below which pelvic injuries do not occur.

751167. (P-62) **Simulation of Collisions Between Pedestrians and Vehicles Using Adult and Child Dummies.** G. Stcherbatcheff, C. Tarriere, P. Duclos and A. Fayon, Laboratory of Physiology and Biomechanics, Peugeot-Renault; C. Got and A. Patel, I.R.O., Raymond Poincare Hospital - Garches.

Collisions between vehicles and pedestrians are analyzed, in conjunction with a bidisciplinary "pedestrian" investigation, by simulating accidents using adult and child dummies. A series of experimental collisions were carried out at varying impact speeds with a sample of vehicles representative of the various front-end profiles of vehicles at present running on the roads, the purpose being to study how these profiles affect the kinematics of the adult and child and to define the risks of injury during the different phases of the accident. The degrees of severity of the impact against the vehicle and the ground are compared and head impact speeds analyzed. Countermeasures are proposed and an initial evaluation made using a cadaver.

751168. (P-62) **The Effect of Variable Load Energy Absorbers on the Biodynamic Response of Cadavers.** Paul C. Begeman and Albert I. King, Wayne State University.

Several types of energy absorbers were tested on a sled simulating a crash deceleration using instrumented, seated erect dummies and cadavers. The energy absorbers were mechanical load limiting devices which attenuated the impact by yielding or tearing of metal. Their principal effects were to reduce the peak deceleration sustained by the occupant with the expected reduction in restraint forces. Constant load level energy absorbers were found to be unattractive because they can easily "bottom out" causing forces and body strains which could be much higher than those without absorbers.

Head accelerations were significantly reduced by the energy absorbers as well as some body strain. However, spinal strains in the cadaver were not significantly reduced. They appear to be not only a function of the peak deceleration level but also of the duration of the pulse.

751169. (P-62) **Significance of Rate of Onset in Impact Injury Evaluation.** David C. Viano and Charles W. Gadd, Biomedical Science Department Research Laboratories, General Motors Corp.

The concept of rate of onset as an injury potential index is critically discussed through the analysis of a wide range of noninjurious whole body decelerations and localized impacts. Examination of the physical data shows that extremely high rates of onset are tolerable without injury and that these levels of rate of onset are reciprocally dependent on the pulse rise time. The physical data are next discussed with reference to existing acceleration injury criteria, specifically the GSI and HIC indices. This work substantiates the conclusions that a single rate of onset tolerance level is not warranted and that rate of onset is not a proven injury potential index.

751170. (P-62) **Front Passenger Passive Restraint for Small Car, High Speed, Frontal Impacts.** David J. Romeo, Calspan Corporation.

A front passenger passive restraint system has been developed which provides frontal impact protection under small car, high speed crash conditions. The system consists of an extended crushable dashpanel, a knee bar and a relatively small volume air bag. Computer simulations, static tests and sled tests have been used to develop this system for the range of occupant sizes from 6 yr. child to 95th percentile adult for crash speeds to 50 mph. This paper reviews these efforts and presents observations regarding not only the performance of the system but those concerned with production feasibility and consumer acceptance as well.

This research was conducted under contract to the U. S. Department of Transportation, NHTSA, under Contract DOT-HS-4-00972.

751171. (P-62) **Injury Predictions for Frontal Collisions.** L. G. Watson and A. C. Shiels, Transportation Centre, University of Saskatchewan.

This paper discusses the development and application of empirical equations relating vehicle damage as expressed by the Collision Deformation Code to occupant injury as expressed by the A.M.A.'s Abbreviated Injury Scale. The discussion deals only with front collisions. Different equations for unrestrained, lap belt restrained and three-point harness restrained front seat occupants are presented. A brief comparison is also made between the actual injuries sustained by crash victims restrained by Air Cushion Restraints and the injuries predicted for occupants restrained by lap and shoulder harness in similar collision configurations.

751172. (P-62) **Dynamic Response of the Spine During +Gx Acceleration.** P. Prasad, N. Mital, A. I. King and L. M. Patrick, Wayne State University.

A review of the existing mathematical models of a car occupant in a rear-end crash reveals that existing models inadequately describe the kinematics of the occupant and cannot demonstrate the injury mechanisms involved. Most models concentrate on head and neck motion and have neglected to study the interaction of the occupant with the seat back, seat cushion, and restraint systems. Major deficiencies are the inability to simulate the torso sliding up the seat back and the absence of the thoracic and lumbar spine as deformable, load transmitting members.

The paper shows the results of a 78 degree-of-freedom model of the spine, head, and pelvis which has already been validated in $+G_z$ and $-G_x$ acceleration directions. It considers automotive-type restraint systems, seat back, and seat cushions, and the torso is free to slide up the seat back. Results of simulation runs show a good correlation with the existing data and experimental cadaveric runs made with a high seat back (or head restraint) and low seat back. The effect of seat-back stiffness and the restraint system on the response of the head and spine is studied.

751173. (P-62) **An Experimentally Validated 3-D Inertial Tracking Package for Application in Biodynamic Research.** E. Becker, Naval Aerospace Medical Research Laboratory Department; and G. Willems, Naval Aerospace Medical Research Laboratory Detachment.

A six-accelerometer inertial tracking package currently in intensive use in measuring living human and human surrogate response to impact acceleration is presented and discussed. The discussion includes an enumeration of the various requirements imposed upon the package as well as its design and fabrication.

The on-site calibration facility is described, including a discussion of the procedures for routine calibration of the packages. Accounts of the data acquisition link from the packages through the sled borne amplifiers to the hybrid computer are also included.

Particular attention is devoted to the theoretical aspects of this system. A statement of errors is developed and compared to the various precision parameters of this system and to a general estimation of the dynamic response envelope demonstrating the overall feasibility of this approach.

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751175. (P-62) **The Primate as a Model for Crash Injury.** Leon E. Kazarian,, 6570th Aerospace Medical Research Laboratory, Wright-Patterson AFB.

In this investigation, a number of anesthetized rhesus monkeys, baboons, and chimpanzees were subjected to a $+G_z$ rectangular deceleration-time history. The parameters of deceleration versus average time duration were plotted as a function of spinal trauma to come up with a series of sensitivity curves based on spinal injury for three families of sub-human primates. The locus, distribution, type, and severity of vertebral body fracture was distinguished on post-impact roentgenographs. The primates were euthanized and the process of documenting and interpreting spinal trauma was repeated following necropsy and water maceration of the soft tissue. The mechanics of vertebral injury were identified. Normal

skeletal geometry and proportionate torso kinesiology of the rhesus monkey, baboon, and chimpanzee and man were compared. The peculiarities and consistencies in injury distribution and their variations were interpreted in terms of distinctive vertebral morphology and functional kinesiology of each animal model. The distinguishing variations in injury patterns and their distribution was related to the scatter of human vertebral injury as reported in aircraft escape system accelerations, crash decelerations, and clinical statistics.

751176. (P-62) **The Contribution of Physical Analysis of Accidents Towards Interpretation of Severe Traffic Trauma.** C. Tarriere, A. Fayon and F. Hartemann, Laboratory of Physiology and Biomechanics, Peugeot-Renault; and P. Ventre, Renault Research and Development Division.

Much progress has been made in many countries during recent years in detailed research into road accidents. The analysis facilities used by research workers to describe in a common language the severity of injuries and the deformation the vehicles undergo are improving.

Assessment of the constraints to which the occupants of crashed vehicles are exposed is still too approximate, despite the fact that this is essential to interpret the progress achieved in the field of safety and to make decisions concerning the future.

The methods used to analyze and classify accidents must reside on unquestionable physical basis. This is why Renault and Peugeot have discarded the Equivalent Test Speed method, replacing it by the Speed Variation method (V) and, more recently, analysis based on two parameters, namely the speed variation and the mean deceleration of the undistorted part of the vehicle.

Application of these methods to a sample of accidents representative of the French situation is presented and discussed in the light of the severity of the lesions observed.

1975 SAE Transactions

751177. (P-61) **Energy Conservation Via Airplane Powered Wheels.** A. W. Waterman, Boeing Commercial Airplane Co.,.

Up to 5% of an airplane's fuel might be saved by taxiing with powered wheels. Additional benefits in conservation are reduced noise, jet blast, and emissions at the terminal area. By using the airplane onboard auxiliary power unit (APU) to operate the traction-producing drives, an airplane self-contained ground-maneuvering capability is provided. Hydraulic power transmission for the wheel drives has the advantage in satisfying large horsepower demands for a small weight and volume penality. Variations in the drive mechanism are based on the method of transfer of power to the wheels while preserving the present method of independent braking during airplane landings.

1975 SAE Transactions

751178. (P-61) **Energy Storing Mechanical Power Package for Aircraft Utility Functions.** C. W. Helsley, Jr., Rockwell International.

Energy storage substations using flywheels for energy storage have been demonstrated to be practical for application to aircraft, but a practical method for introducing energy to and extracting energy from the flywheel has not been demonstrated for utility applications. A program is under way to design, build, and test a mechanical power package (MPP) for operating the B-1 bomber main landing gear. This program is being sponsored by the Air Force under Contract F33615-75-C-2011. The MPP will include a mechanical infinitely-variable traction transmission for input and extraction of energy, and will also be used to investigate certain methods for reducing energy loss. This paper reports these methods and summarizes the test program.

1975 SAE Transactions

751179. (P-61) **Hydraulic Fluidborne Noise Mechanics.** Stanley J. Skaistis, Sperry Vickers.

The discharge pressure pulsation emanating from hydraulic pumps is called Fluidborne Noise because it can excite other circuit components into radiating audible noise. Cut and try methods are often used to solve problems caused by this form of vibratory energy. It is felt that a better understanding of the mechanics of fluidborne noise can lead to more efficient approaches to such problems. This paper discusses these mechanics including the generation of fluidborne noise pumps, its characteristics, how it is minimized by pump design, the formation of standing waves, measurement of this noise and some of the methods used to abate it.

751180. A Continuously Variable Transmission for Automotive Fuel Economy. J. H. Kraus, C. E. Kraus and M. E. Gres, Excelermatic, Inc.

The use of a high efficiency, continuously variable transmission (CVT) with a wide ratio range is required in order to operate an automotive engine at minimum brake specific fuel consumption (bsfc). Such operation will increase fuel economy from 20-40% over conventional practice.

This paper describes a 12:1 ratio range CVT, and shows a simplified control system capable of allowing a vehicle to operate with the engine at or very near minimum bsfc under all demand power conditions for optimized fuel economy.

Also described is the effect such a transmission has on vehicle performance and raises the possibility of reducing engine size to maintain normal performance, and further increase fuel economy.

1975 SAE Transactions

751183. Advanced Cooling Systems for Agricultural and Industrial Machines. Arthur E. Bergles, George H. Junkhan, John K. Hagge and Michael K.

Jensen, Mechanical Engineering Dept., Iowa State University.

This paper describes a number of major modifications and alterations which have the potential to improve engine cooling systems for agricultural and industrial machines.

Of the passive augmentation schemes studied (packed-beds, gas/solid suspensions, and spray cooling), spray cooling is the only one which has potential for practical application, but only for intermittent use to avoid overdesign of conventional cooling systems.

The active augmentation techniques considered (surface scrapers, acoustic vibrations, and electric fields) involve additional system complexity. Acoustic vibrations and electric fields are not effective enough to justify their use in augmentating heat transfer in conventional cores. Recent laboratory tests of the surface scraping technique indicate that this method is very effective for improving heat transfer to air flows.

Studies of several new cooling arrangements indicate that direct contact heat exchangers and vaporization and condensation of engine coolant would probably not work as improved cooling systems. On the other hand, the following arrangements can reject large amounts of heat: tire heat exchangers, implement heat exchangers, and radiative-convective cooling panels. One or several of these arrangements could be attractive when used in combination with a smaller conventional heat exchanger.

751184. Inching Toward Meters. Katherine Munsen, Iowa State University.

Early measuring systems are reviewed substantiating the need for a single rational system of measurement. The metric system is traced briefly from its beginning in France to the present day. Fundamental units, the gram, meter, liter and degrees Celsius are discussed in conjunction with the basic prefixes---kilo, centi, milli. The simplicity of the metric system should encourage the homemaker as she prepares to purchase food and fabric in metric units and prepares food with metric measuring utensils. Sizes of metric measuring utensils for food preparation is discussed. Industry and government will give direction for a smooth conversion from inches to meters.

751185. A Comparative Analysis of Radial and Bias R-1 Drive Wheel Tractor Tires. L. F. Bohnert and T. D. Kenady, B. F. Goodrich Tire Co.

Since the pneumatic farm tire was developed, the basic carcass construction has been bias or diagonal plies. As tractor manufacturers continue to produce models with higher and higher horsepower, it has become evident that the conventional design changes--lug shape, lug angle, aspect ratio, etc.--are no longer sufficient to achieve significant improvements in tractor drive wheel tire performance. After investigating various alternatives, B. F. Goodrich determined that a radial construction offered distinct performance advantages over a bias construction without requiring any redesigning of the tractor. These include: increased traction, reduced fuel consumption, longer wear and improved ride. This paper will present comparative performance results of radial and bias drive wheel tractor tires, and discuss the basic radial tire mechanics which make the performance improvements possible.

751187. Introducing a New Generation of More Detailed and Informative Combustion Models. Frediano V. Bracco, Guggenheim Labs. Princeton University.

The problem of modeling combustion within internal combustion engines is considered. A method is explained to evaluate the comprehensiveness, detail and predicting capability of a model. It consists of considering the equations for the most comprehensive and detailed model and in making successively more restrictive assumptions, thus getting progressively less detailed models. Particular attention is paid to the reasons for the assumptions, how they influence the accuracy of a model, and what basic information is missing. In so doing, the most detailed of the available models, and their predictive capabilities and limitations, are introduced. They include models for reciprocating and rotary engines, with uniform and stratified charges from dual carburetion and direct fuel injection. Examples of their results are given. One of them has been available since 1971, and another one is currently and fruitfully employed to aid the development of a production engine. Also introduced are more advance models presently under development and their applications. The equations of the most common and least detailed models are derived from the most general equations, thus evidencing their inherent limitations.

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The purpose of this section is to make the literature developed by the Society more useful to the engineering community. This is done in three ways.

A SUBJECT INDEX containing all the literature produced during the year. Each individual paper or piece of literature is listed several times under the subject headings that are appropriate to its technical content.

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The staged combustion compound engine (SCCE): exhaust emissions and fuel economy potential
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High chemical activity of incomplete combustion products and a method of prechamber torch ignition for avalanche activation of combustion in internal combustion engines
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Combustion process fundamentals and combustion chamber design for low emissions
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Injury predictions for frontal collisions
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The primate as a model for crash injury
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Future hydrogen fueled commercial transports
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Combustion Chambers
Development of a high speed four-cylinder diesel engine under consideration of the existing machine-tools equipment for the production of the gasoline engines
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The variable ratio master cylinder —a description of its function and operation
1975 SAE Trans.
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The measurement of the turbulence characteristics in an internal combustion engine cylinder
750886

Data acquisition
Measurement and analysis of engine pressure data
1975 SAE Trans.
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Digital data acquisition with emphasis on measuring pressure synchronously with crank angle
750028

Limits of ride quality through cab isolation
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A prognostic simulation technique for fluid power systems
1975 SAE Trans.
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An historical overview of research in traffic accident
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A discussion of data gathering systems
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1975 SAE Trans.
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Automated accident reconstruction
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1975 SAE Trans.
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Aircraft Design
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Dunlop composite energy absorbing bumper systems
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Computer aided design of body roof side rail
750021

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750051

High performance ignition components with Celanex thermoplastic polyesters
750059

Boss-fastener strengths with SMC materials
750063

Draw bead design for deep profiles
750130

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Arizona State University's design approach to the REV-74 competition
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Design in a textile revolution
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HEI - A new ignition system through new technology
1975 SAE Trans.
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Controls reach — the hand reach of drivers
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Restraint systems: a human engineering evaluation
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Radial ply tires—how different are they in the low lateral acceleration regime
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The effect of belt materials on performance of radial passenger tires
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Tire induced steering pull
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What is a microprocessor?
1975 SAE Trans.
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Application of microprocessors to the automobile
750432 (SP-393)

Mass transportation vehicles and people movers
750440

The role of lubricant additives in controlling abnormal combustion (ORI)
750449

Manufacturing the third generation econoline
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Thermal/voltage response characteristics of automotive nonantimonial lead-acid batteries
750471

Evaluation of two convex mirror systems by government drivers
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Field service history analysis for ground vehicles
1975 SAE Trans.
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Design concepts of the JD770 motor grader
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Colony development operation oil shale: mining and recovery of oil
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Link pin seals on off-highway equipment
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Construction of the Polar Star, a shipyard view
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Protecting the operator from the hostile environment of woods operation
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Design and development of the caterpillar 7155 semi-automatic heavy-duty truck transmission
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New developments in piston rings for the modern diesel engine
1975 SAE Trans.
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Characterization and simulation of a unit injector
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Energy conservation—electric forklift hydraulic systems
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Today's mineral problems and a look at the coming decade
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Optimizing transmission bearing selection and assembly
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Hydraulically boosted brakes—an important part of central hydraulic systems
1975 SAE Trans.
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The thermal performance of automotive disc brakes
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Turbulent flow in spark ignition engine combustion chambers
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Failure survival aspects of a digital fuel control system
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Vectored lift advanced fighter technology integrator
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Modern aviation turbine fuel handling systems
1975 SAE Trans.
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The diesel engine for truck application
1975 SAE Trans.
750128 (SP-391)

Feasibility of cooling diesel engines by introducing water into the combustion chamber
1975 SAE Trans.
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Cooling higher horsepower highway diesel engines
750131

Estimation of contributed noise levels of diesel engine components from vibration measurements
1975 SAE Trans.
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Cooperative evaluation of techniques for measuring nitric oxide and carbon monoxide (phase IV tests)
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A light duty diesel for America?
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The light duty diesel engine for private transportation
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Emissions and economy of four diesel cars
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A diesel engine for light duty applications
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Experience with comprex pressure wave supercharger on the high-speed passenger car diesel engine
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Comprex supercharging of vehicle diesel engines
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Development of a high speed four-cylinder diesel engine under consideration of the existing machine-tools equipment for the production of the gasoline engines
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Scheduling injection timing for reduction of diesel emissions
750337

A computer program for calculating properties of equilibrium combustion products with some applications to I.C. engines
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Effect of alcohols as supplemental fuel for turbocharged diesel engines
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Preparation and operation of diesel engines in construction and industrial machinery for operation in cold climates
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Energy conservation: optimization of the vehicle-fuel-refinery system
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Emissions patterns of diesel-powered passenger cars
1975 SAE Trans.
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Army experience with synthetic engine oils in mixed fleet arctic service
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Diester synthetic lubricants for automotive and diesel applications
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New developments in marine propulsion controls
750715

Energy economics of automotive power generation
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Direct utilization of crude oil as a fuel for high-speed diesel engines
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Small bore diesel engine testing using the fractional factorial technique to evaluate oil control
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A new diesel injection pump with high injection rate, its influence on smoke and emissions
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Multi-purpose engine lubricant for mixed fleet operation
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Experiences with multigrade heavy duty engine oils in military gasoline and diesel engines
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750797 (SP-397)
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1975 SAE Trans.
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Piston slap noise of indirect combustion diesel engine
750801 (SP-397)

Injection noise and its relation to fuel pump and engine noise
750802 (SP-397)

Identification and modeling of rotary fuel injection pump noise processes
750803 (SP-397)

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Simple model technique for better understanding of diesel engine vibration and noise
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The application of idealization and response analysis to diesel engine noise assessment
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Practical means for reducing the noise of fast diesel engines
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Design concepts of diesel engines with low noise emission
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Low noise opposed piston two-stroke engine and blower
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A fundamental investigation into the problem of NO formation in diesel engines
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Design and results of the five-cylinder Mercedes-Benz diesel engine
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The use of constant volume sampler and dilution tunnel to compare the total particulates from a range of automotive engines
750904

The diesel as an alternative automobile engine
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Emission formation characteristics of the diesel combustion process and estimated future development trends
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Diesel fuels
The electric multistop fleet delivery vehicle—fact or fantasy
750075

Investigations concerning the employment possibilities of the diesel-gas process for reducing exhaust emissions, especially soot (particulate matters)
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Diesel smoke
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Emissions and economy of four diesel cars
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Efficient and clean diesel combustion
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Advanced method for reduction in axle gear noise
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Disc brakes
The manufacture of disc brake linings
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Stepped bore master cylinder—a way of improving dual brake systems
1975 SAE Trans.
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1975 SAE Trans.
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Air wedge disc brakes for heavy truck front axles
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The thermal performance of automotive disc brakes
1975 SAE Trans.
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On and off-board brake system monitoring status and prospects for the future
750875

Pad wear indication for disc brakes
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Evaluation of gray iron brake discs for trucks by thermal modeling
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Measurement of motor vehicle operation pertinent to fuel economy
1975 SAE Trans.
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The role of vehicle handling in accident causation
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Restraint systems: a human engineering evaluation
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Comparison of eye fixations of operators of motorcycles and automobiles
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Why your best life insurance is a passive restraint
750390

Passive versus active = life versus death
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Car design for economy and emissions
1975 SAE Trans.
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Driver-vehicle performance in closed loop tests
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Seat belt use inducing system effectiveness in fleet automobiles
751006

Driving simulators
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Dynamometers
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750210

Automotive exhaust sensors using titania ceramic
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750419 (SP-395)

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Emissions control of gasoline engines for heavy-duty vehicles
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A new five-speed manual transmission for passenger cars
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Gasoline engine economy—a European viewpoint
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Inertia brake dynamometer testing techniques for FMVSS 121
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Economic conditions
The low-sulfur unleaded gasoline problem
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Steel capacity and critical raw materials: an outlook for growth
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Aircraft safety: the missing link —passenger education
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Training materials for agricultural safety and health
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The application of elastomeric buckling columns in an energy management bumper system
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Epoxies and urethanes—changing times breed new products
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The operation of elastomeric radial lip seals at high temperatures
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The application of NMR spectroscopy to the analysis of automotive plastics
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Paint considerations of coating flexible substrates
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The long-term heat resistance of epichlorohydrin hose and tubing compounds
1975 SAE Trans.
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Ethylene propylene elastomer technology for improved high temperature serviceability
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High performance ignition components with Celanex thermoplastic polyesters
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The design and testing of a completely waterproof electrical connector for automotive use
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Electrical propulsion systems for battery driven road vehicles with hydrodynamic transmission of power
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750368 (SP-393)

Closed loop carburetor emission control system
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Design considerations for an on-board computer system
750434 (SP-393)

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750438 (SP-393)

Remote control bobcat loader
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Field test experience with new electronic governor
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Digital FWB flight control and related displays
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ACT system design for reliability, maintainability and redundancy management
1975 SAE Trans.
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Electronic fuel controls for missile and RPV gas turbines
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Evolution of an electronic fuel control for industrial gas turbines
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750202 (SP-393)

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Electronic equipment earning its place on European vehicles
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Programable energy ignition system for engine optimization
1975 SAE Trans.
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750368 (SP-393)

Electronic Optimizer control for I.C. engine: most MPG for any MPH
750370 (SP-393)

Conductive ceramics for use in the Na-S battery
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1975 SAE Trans.
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750432 (SP-393)

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750433 (SP-393)

Electronic fault monitoring and diagnosis in air bag systems
1975 SAE Trans.
750436 (SP-393)

Electronic air core wide angle tachometer
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750438 (SP-393)

Dynamic method for storage battery diagnostic testing
1975 SAE Trans.
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Energy conservation—electric forklift hydraulic systems
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What are the benefits of monitoring?
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Pad wear indication for disc brakes
1975 SAE Trans.
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Computer monitored programmable controller systems
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Failure survival aspects of a digital fuel control system
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Fairchild republic advanced fighter technnology integrator (AFTI) —phase 1 program review
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Remotely piloted vehicle technology development using the XQM-103 research test vehicle
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Electric propulsion
Nickel-zinc storage batteries as energy sources for electric vehicles
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A quiet, efficient controller for electric vehicles
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Ground transportation system for Bradley International Airport
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Electric wire
Effect of wax, plasticizer, and high humidity on adhesion of polyurethane bonded chloroprene to primed steel
750139

Electronic packaging
Design of electronics for the automotive environment
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Electronic display applications in instrument panel design
1975 SAE Trans.
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Electron microscopy
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A coating for the preservation of fracture surfaces
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Emissions control
Teledyne Continental Motors red seal engines first CPCS application
750017

Design and special development problems of Mercedes-Benz V-8 engines
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The influence of transient conditions on the operation of an SI engine, especially with respect to exhaust emissions
750053

The Carter system—a new approach for a steam powered automobile
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Sulfuric acid and nitrate emissions from oxidation catalysts
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The low-sulfur unleaded gasoline problem
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The conversion of SO_2 over automotive oxidation catalysts
1975 SAE Trans.
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Effect of three way conversion catalyst operation on the chemical state of automotive sulfur emissions
750096

Some phenomena which control sulfuric acid emission from automotive catalysts
750097

Single-cylinder engine evaluation of methanol—improved energy economy and reduced NO_x
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Pulsair—a method for exhaust system induction of secondary air for emission control
1975 SAE Trans.
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Exhaust-port fuel injection for chemical reduction of nitric oxide
750173

The importance of secondary air mixing in exhaust thermal reactor systems
750174

Dual catalytic converters
750176

Reliability analysis of catalytic converter as an automotive emission control system
1975 SAE Trans.
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Catalytic emission control system field test program
750179

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1975 SAE Trans.
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Emissions and economy of four diesel cars
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Significance of burn types, as measured by using the spark plugs as ionization probes, with respect to the hydrocarbon emission levels in S.I. engines
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Bosch electronic fuel injection with closed loop control
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An approach to the low emission engine with the consideration of fuel economy
750416 (SP-395)

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1975 SAE Trans.
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1975 SAE Trans.
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Effect of alcohols as supplemental fuel for turbocharged diesel engines
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1975 SAE Trans.
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Exhaust sulfur oxide measurement using air dilution
1975 SAE Trans.
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Methanol/gasoline blends as automotive fuel
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A new diesel injection pump with high injection rate, its influence on smoke and emissions
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Efficient and clean diesel combustion
750787

The water-cooled Volkswagen PCI-stratified charge engine
1975 SAE Trans.
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Durability and fuel economy experience with dual bed catalyst system
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Comparison of automotive catalytic honeycomb structures through two-dimensional thermal stress analysis
1975 SAE Trans.
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A laser interferometer study of combustion near an ignition source in a static chamber
750887

Combustion and exhaust emission of an engine using the Porsche-stratified-charge-chamber-system
750888

Deposits, wear, and catalyst performance with low ash and ashless engine oils
1975 SAE Trans.
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Exhaust emissions from heavy-duty trucks tested on a road course and by dynamometer
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Emissions control of gasoline engines for heavy-duty vehicles
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The use of constant volume sampler and dilution tunnel to compare the total particulates from a range of automotive engines
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Catalytic control of two-stroke motorcycle exhaust emissions
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1975 SAE Trans.
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An evaluation of alternative power sources for
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The diesel as an alternative automobile engine
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Problem areas in sampling and analyzing VCM
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Material alternatives for today's emission control system
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Energy conservation via airplane powered wheels
1975 SAE Trans.
751177 (P-61)

Energy conversion
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Energy economics of automotive power generation
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Today's mineral problems and a look at the coming decade
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An overview of the sodium-sulfur battery
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A Method for Estimating Mileage Improvement and Emission Reductions Achievable by Hybrid-Electric Vehicles
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Engine cooling system of military combat/tactical vehicles
1975 SAE Trans.
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Deposits, wear, and catalyst performance with low ash and ashless engine oils
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Some factors which affect octane requirement increase
1975 SAE Trans.
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The light duty diesel engine for private transportation
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A diesel engine for light duty applications
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Air intake silencing for small engines
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750798 (SP-397)

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Practical means for reducing the noise of fast diesel engines
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Techniques for quieting the diesel
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Noise—the diesel engine designers' dilemma
750841 (SP-397)

European practice in respect of automotive cams and followers
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Design and results of the five-cylinder Mercedes-Benz diesel engine
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Applied photoelasticity for engine component design
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Lean burn engine concepts—emissions and economy
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A continuously variable transmission for automotive fuel economy
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Factors influencing engineers' productivity
1975 SAE Trans.
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Engine mounting
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Automotive fuel savings through selected lubricants
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1975 SAE Trans.
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A test procedure for evaluating temporary-shear loss of engine lubricants
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Waste oil management from sump to end use — a status report
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A joint venture of recycling in plant waste oils
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Field service compatibility of ashless and fully compounded engine oils with two bead-type oxidation catalysts
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Army experience with synthetic engine oils in mixed fleet arctic service
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Vehicle evaluation of synthetic and conventional engine oils
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1975 SAE Trans.
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Low temperature viscosity requirements of the Italian car population
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European practice in respect of automotive cams and followers
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Aerospace Engines
Aircooled Engines
Compound Engines
Diesel Engines
Energy Conversion
External Combustion Engines
Gas Engines
Gasoline Engines
Industrial Engines
Marine Engines
Reciprocating Engines
Rotary Combustion Engines
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Spark Ignition Engines
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Each piece of literature is assigned a six-digit code number. Most papers are published separately in booklet form. However, from time to time groups of papers on the same subject are grouped together in one "Special Publication." Papers presented before each Conference of the Society are published together in a "Proceedings." The following list cross-references the six-digit code number with the Proceedings volume number (P) or the Special Publication number (SP).

For your information, a list of the titles of the Special Publications and Conference Proceedings follows at the end of the cross-references.

750128 – SP-391

750133 through 750136 – SP-392

750200 through 750202; 750364 through 750371; 750431 through 750438 – SP-393

750414 through 750420 and 750451 – SP-395

751001 through 751004 – SP-396

750795 through 750803; 750832 through 750841 – SP-397

751120 – SP-398

751141 through 751176 – P-62

SP-391 - The Diesel Engine for Truck Application

SP-392 - Vehicle Analytical Design for Structural Criteria—An Overview

SP-393 - Automotive Electronics

SP-395 - Inter Industry Emission Control, Program 2, Progress Report No. 1

SP-396 - Engine Design to Meet New Social Obligations

SP-397 - Diesel Engine Noise

SP-398 - Powerplants—Past, Present and Future

P-62 - 19th Stapp Car Crash Conference

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